3. SITE PHYSICAL DESCRIPTION

This chapter provides a description of the relevant physical, ecological and social characteristics of the Landsburg Mine site and Study Area. Descriptions are presented of the site location and topography, waste source characteristics, geology, mine history and condition, surface water hydrology, hydrogeology, meteorology, social characteristics and ecology.

3.1 Site Location And Topography

The Landsburg Mine site consists of a former underground coal mine located approximately 1.5 miles northwest of Ravensdale in a rural area of southeast King County, Washington. The site is situated directly south and east of the S.E. Summit-Landsburg Road and north of the Kent-Kangley Rd (State Highway 516). Downtown Seattle is approximately 20 miles to the northwest. The Cedar River passes within approximately 500 ft of the site to the north. The location of the site is shown in Figures 1-1, 1-2 and 1-3. The topography of the site and general site features are depicted in Figure 3-1. An aerial image of the site is shown in Figure 2-16.

The mine site occupies property owned by Palmer Coking Coal Company (PCC) and Plum Creek Timber Company, L.P. and is located within sections 24 and 25, Township 22 N., Range 6 E. Figure 1-4 depicts the PCC and Plum Creek Timber property boundaries at the site. The site is located in the northwest corner of the Cumberland 7.5 minute quadrangle along the boundary with the Hobart quadrangle.

The *Landsburg Mine site* was defined in the Work Plan (Golder 1992a) as land extending 400 feet on either side of the mine trench lineation and bounded by the S.E. Summit-Landsburg Rd. to the north and the electrical transmission line easement to the south. A defined Study Area for the site, prescribed by Ecology for the purposes of this RI/FS, is depicted in Figure 1-2. In general, the Study Area was intended to include the area within an approximately one-half mile radius of the Rogers trench (Golder 1992a).

Apart from the Mine, the only development in the Study Area is residential with approximately 90 residences contained within the Study Area. The nearest residences to the site are to the southwest approximately 800 ft from the trench. Drinking water for area residences is supplied by groundwater, either through private wells or small community water supply systems. Domestic sewage disposal throughout the Study Area is provided by residential septic systems.

A dirt road accesses the property and trails run parallel to the east and west sides of the trench. The access road begins near S.E. Summit-Landsburg Road and follows along the northern portion of the trench. A locked gate secures the site at the access road entrance, and the portion of the trench where disposal occurred is currently enclosed by an 8 ft tall chain link security fence. Dense vegetation covers the site and includes blackberry, alder, cedar, hemlock, cottonwood, maple and fir.

The Landsburg Mine property sits atop a gently sloping hill which reaches a maximum elevation of approximately 800 ft mean sea level (MSL) near the central portion of the site. At the site's northern end (Figure 3-1), this hill slopes steeply downwards towards the S.E. Summit-Landsburg Rd. (elevation of approximately 615 ft) and continuing to the Cedar River (elevation approximately 500 ft). The southern portion of the site slopes more gradually downwards to the south toward the Kent-Kangley Rd. and Rock Creek drainage located at an elevation of approximately 600 ft. The site is bounded to the east by a somewhat larger hill which rises to a maximum elevation of approximately 940 ft.

Electrical transmission lines and a Bonneville Power Administration property easement cross the southern portion of the site in an east-west direction. Approximately 3/4 mile upstream of the site along the Cedar River at Landsburg, the City of Seattle Water Department maintains a drinking water supply intake known as the Landsburg Diversion. Water is conveyed from the intake through a 96-in diameter pipeline to the Lake Youngs Reservoir, located some 5 miles to the northwest of Landsburg (Brown and Caldwell 1978a). The pipeline passes just to the north of the site and is located near the bottom of the slope between the S.E. Summit-Landsburg Rd. and the Cedar River. An unpaved service road (Pipeline Road) parallels the pipeline right-of-way. A meteorologic data collection and river gaging station, operated by the City of Seattle, are located at the water intake structure. The location of the supply intake is shown in Figure 1-2. Pipeline Road is depicted in Figure 3-1. Approximately 1 mile upstream from the Landsburg Diversion on the Cedar River, a river gaging station is maintained by the USGS (Landsburg Gaging Station).

3.2 Source Characteristics

This section describes information regarding the characteristics of the wastes disposed in the Rogers trench. This information includes data reported in previous investigations as well as information gathered in this RI. Waste characterization activities conducted as part of this RI consisted of the Task 8 Geophysical Investigation described in Section 2.6.1.

3.2.1 Site Mining and Waste Disposal Activities

Palmer Coking Coal (PCC) operated an underground coal mine known as the Landsburg Mine from the late 1940s until approximately 1975. Mining was conducted in two adjacent coal seams: the Landsburg seam and the Rogers Seam. Mining began in the Landsburg seam in the late 1940s and continued until 1959. In 1959, mining of the Landsburg seam ceased and mining began on the Rogers Seam. The Rogers Seam was mined from 1959 until 1975 when all active mine openings were closed by blasting. In addition to these two coal seams, the Frasier seam, located some 800 ft to the north of the Rogers Seam, was mined intermittently from the 1800s to the mid-1940s. Figure 3-2 depicts the layout of the mines completed within the three seams.

The mined section of the Rogers coal seam has a near vertical dip and consists of coal and interbedded shale approximately 16 ft wide. The mined section is about a mile in length. Mining occurred at depths of up to 750 feet using a mining method locally called "booming" which followed the coal seam vertically. The reader is referred to Section 3.4 for a detailed history of mining at the site (specifically in the Rogers Seam) and a description of mining methods used.

As a result of underground mining at the site, a subsidence trench with near vertical walls developed on the land surface above the mine workings. The dimensions of the trench vary, from about 60 to 100 feet wide, between 20 to 70 feet deep, and about 3/4 mile long. The trench is not continuous along its whole length but is comprised of a series of separate subsided segments. Each trench section is separated by a pillar wall. Figure 3-3 depicts a topographic profile along the centerline of the mine trace.

Available information on the prior waste disposal activities at the site are summarized in Ecology and Environment (1991), Landsburg PLP Steering Committee (1991) and Golder (1992b) from which this discussion is based. Beginning in 1969, the trench over the Rogers Seam was used for the disposal of various waste materials, including industrial wastes, construction and land-clearing debris, tires and miscellaneous household garbage. Materials were disposed into the mine trench from the site access road indicated in Figure 3-1.

Industrial wastes were contained in drums or dumped directly from tanker trunks. Based on invoice records from Palmer Coking Coal Company, an estimated 4,500 drums of waste and about 200,000 gallons of oily waste water and sludges were disposed into the trench. Available documented interviews with waste haulers indicate that wastes included paint wastes, solvents, metal sludges and oily water and sludge (WDOE 1990). It is expected that many of the drums were only partially full. While disposal of materials into the trench continued intermittently until 1983, the last documented disposal of hazardous substances was in 1978, as described in the waste disposal summary below:

1969	Disposal of industrial wastes including drummed wastes and land clearing debris in the trench. The specific nature of the industrial wastes placed at the site is unknown (WDOE 1990).
Summer of 1971	Fires occurred in the trench on June 16 and 28, July 22, and August 2 and 3 (Office of the Zoning and Subdivision Examiner 1974).
August 16, 1971	The King County Department of Building and Land Development placed a stop work order on dumping operations due to the fires (WDOE 1971).
August 28, 1972	The King County Council approved, on recommendations of the Zoning and Subdivision Examiner, an unclassified use permit for Palmer for a period of 5 years (proposed ordinance number 71-631). This permit allowed disposal of stumps, brush, natural vegetation, and earth cover materials (WDOE 1972).
1972-1978	No evidence of industrial waste disposal activity.
May/June 1978	A complaint was filed with Ecology that on May 18, 1978, a double-unit tanker truck was observed entering the Mine property. As a result of the complaint, it was determined that approximately 30,000 gals of oily sludge had been disposed of in the trench in an operation which commenced in May 1978. Operations were halted in June 1978 by Ecology (WDOE 1990).

1983 The trench reportedly was being filled with demolition debris. Evidence of nonhazardous materials, including scrap lumber and construction debris, and old drums from previous activities were observed in the trench (Ecology and Environment 1984).

3.2.2 Previous Investigations

Investigations that provided waste, soil, soil gas, surface water, and groundwater analytical data have been conducted since 1990 and include the following:

- Surface Water Sampling at Landsburg Mine (Geraghty and Miller 1990).
- Soil Gas Survey Report, Old Landsburg Mine Site, Georgetown, Washington (Applied Geotechnology 1990).
- Private Well Sampling and Surface Water Sampling at Rogers #3 Portal - Landsburg Mine, Ravensdale, Washington (Washington State Department of Health 1992).
- Landsburg Mine Site Hazard Assessment (Ecology and Environment 1991).
- Landsburg Mine Drum Removal Project (Landsburg PLP Steering Committee 1991).

Sampling of surface water discharging from Rogers Mine portals #2 and #3 on January 10 and 18, 1990 (Geraghty and Miller 1990) did not reveal any priority pollutant organic compounds or metals, except zinc at 210 μg/L and arsenic at 6 μg/L. The zinc was reported to exceed a Washington State Surface Water Quality Standard of about 0.1 mg/l. At the time of the investigation, there was no State surface water quality criteria for arsenic. The occurrence of the zinc and the arsenic, however, were both attributed in the report to natural background associated with coal deposits and coal mine drainage.

The soil gas survey conducted within the Rogers trench (Applied Geotechnology Inc. 1990) did not detect any priority pollutant volatile organic compounds. Positive readings on OVA-FID and OVA-PID field instruments were attributed to the occurrence of methane.

At the end of winter 1990, groundwater from nine private wells, the City of Kent, Clark Springs Well and the south portal (Rogers #3) were sampled and analyzed for priority pollutant organic compounds and metals (Washington State Department of Health 1992). The analytical results did not reveal any contamination above acceptable drinking water standards. Levels of metals detected were reported to be consistent with those for background water quality. The report concluded that the quality of the drinking water in the Mine area had not been adversely affected by Mine disposal activities.

Therefore, sampling of surface water, groundwater and soil gas during several investigations conducted in 1990 did not detect any contamination above naturally-occurring background levels. Due to continued concerns over potential environmental threats posed by the Mine, Ecology commissioned a Site Hazard Assessment (SHA) study in 1991 which was performed by Ecology and Environment. Ecology then requested potentially liable parties (PLPs) to perform an expedited response action (ERA) to remove surficial drums and secure the site from unauthorized access. These investigations conducted during 1991 did reveal the presence of contaminants above acceptable standards and also included the characterizations of contents within exposed drums. Observations and analytical results of these studies are summarized below.

3.2.2.1 Site Hazard Assessment

In 1991, Ecology and Environment, Inc. (E&E) conducted a Site Hazard Assessment (SHA) for the WDOE pursuant to Chapter 173-340-320 of the MTCA Cleanup Regulation. The SHA included two phases of field work: 1) a site reconnaissance and geophysical survey; and 2) limited drum, surface water and soil sampling and analysis. The second phase of work included the collection of 14 surface and subsurface soil samples from within the trench, surface water samples from 2 ponds, and liquids sampling from three exposed drums. Samples were analyzed for volatile organic compounds, semi-volatile organics, pesticides/PCBs, and cyanide. The locations of the sampling conducted as part of the SHA are indicated in Figure 3-4.

Visual reconnaissance and geophysical surveys indicated that waste material appeared to be confined to the northern half of the trench in three areas (A, B and C) separated by pillar walls. The three sections are shown in Figure 3-4. In these sections of the trench, personnel observed fill areas which were covered by soils along much of the trench floor and sidewalls. These fill areas resulted from past disposal activities, which usually included covering the waste periodically with soil. Native soil generally was bulldozed over the trench edge to cover the waste material. The thickness of introduced fill and naturally eroded soils is unknown.

The waste materials appeared to consist of construction waste (wood and scrap metal), as well as drums containing various organic and inorganic constituents. A major group of approximately 50 exposed drums was observed in Section B (Figure 3-4) and other smaller groupings of drums were noted throughout trench sections B and C. Inspectors noted drum deterioration, bullet holes and liquids/solids within some of the accessible drums. Magnetometer survey results indicated a high likelihood of buried metal (possibly drums) in Section C. Two areas of ponded water were also observed within the trench area both in the vicinity of the exposed drums.

The three drums sampled indicated the presence of concentrated metals, cyanide, VOCs, semivolatile organics and PCBs. These contents indicated the potential for classification of the drum materials as Extremely Hazardous Waste (EHW) or Dangerous Waste (DW) according to Chapter 173-303 WAC. Soil and surface water sampling conducted along the entire length of the trench indicated that, in general, contamination was not found except near a group of drums visible in Section C (sample LS-8) and Section B (LDS-1). MTCA Method B cleanup levels for soil were exceeded at these locations for chromium, lead, bis(2-ethylhexyl)phthalate, and PCBs. Soil chemical data collected as part of the SHA are presented further in Chapter 5 and incorporated into the overall data evaluation performed as part of this RI.

3.2.2.2 Expedited Response Action

During August and September 1991, the Landsburg PLP Steering Committee conducted an expedited response action to remove surficial drums from the Landsburg Mine site. A total of 116 drums were removed during this action. In addition, sampling and analysis was conducted on drum contents, and on oily sludges from a so-called “sludge pond” north of the trench cross-over road.

Drum Removal

Drums were removed from two areas of the site, as shown on Figure 3-5: “Area 1a” and “Area 2”. Area 1, which includes Areas 1a and 1b, corresponds to Section B of the SHA, and Area 2 corresponds to Section C. The SHA identified two areas containing drums in Section B (Area 1). One of these was designated as Area 1a in the drum removal project. However, drums were not found in the second area, which was designated 1b. Area 1b did contain a number of separate fill areas.

At Area 1a, drums were located in a pile starting about 25 to 30 feet below the east rim of the trench and extending down slope 40 to 45 feet. Drums were piled 2 to 5 high and had bullet holes and punctures in the upper layers with many of the drums in the lower layers crushed or deformed. A total of 103 drums were removed from this area. Ten of these were reportedly empty or contained some residues. About 10% of the drums were reported to contain liquids with the rest containing solids and sludgy solids.

Thirteen drums were removed from Area 2. Eleven of these were located around a "sludge pond" area. Ten of these drums were open top without lids and were lying on their sides with some of the contents spilled onto the ground. One of the drums had a ruptured bung type lid. Two additional bung type drums were removed from a stump pile of logging and construction debris located on the northwest bank of the trench just north of the pond area. One of these drums was empty and the other contained green solids. During removal of these drums, ten additional drums were observed mixed in with stump pile debris. These drums were left in place. All the drums in Area 2 had multiple bullet holes or punctures.

Drums were overpacked into 85 gallon drums for removal. Spilled contents were also removed and placed in the overpack drum. If large amounts of liquids were present in the drums, the liquids were transferred to new drums and removed. About 10% of the drums from area 1a were placed in 1 cubic yard bulk bags because they were too crushed or deformed to fit into the overpack drums.

Drum sampling was conducted to classify and characterize the wastes and prepare waste profiles required by the RCRA treatment, storage and disposal facilities where the waste was sent. Only screening level analysis was conducted to determine physical properties and presence of specific regulated substances. Samples were generally composited for screening analysis for:

- physical characteristics - specific gravity, % free liquids, pH, flash point
- oxidizers
- chlorinated compounds

- hexavalent chrome
- cyanides
- sulfides
- phenolics
- PCBs
- total cadmium, chromium and lead

Wastes in the drums were solids, solid/liquid mixtures, sludges or semi-solids. Some of the drums contained free liquids (1 to 50%) and some were burnable. Some of the wastes tested positive for hexavalent chromium, phenolics, chlorinated compounds, and oxidizers. Cyanides and sulfides were not detected. PCBs were detected in 6 of 12 composite samples tested. Concentrations of PCBs were greater than 100 mg/kg in four of the composite samples. Relatively low levels of total cadmium were detected ranging from less than 0.83 to 22 mg/kg. Chromium levels ranged from 62 to 4,900 mg/kg. Lead ranged from 1,000 to 16,000 mg/kg.

Based on these screening level analyses the wastes in the drums have the potential to be classified as DW or EHW for a variety of waste codes. Potential waste designations pursuant to WAC 173-303 include:

- Ignitable (D001) based on flash point and presence of oxidizers,
- Persistent (WP01 or WP02) based on presence of chlorinated compounds
- Toxic Characteristic for chromium (D007) and lead (D008)

This type of screening level analysis is not comprehensive enough to identify all potential dangerous waste codes or for complete comparison with MTCA cleanup standards. However, based on the results, wastes did exceed MTCA Method B cleanup levels for soils in at least some samples for cadmium, chromium, lead and PCBs.

Pond Sludge Sampling

The pond in Area 1A is an area of soft oily sludge and water about 24 feet in diameter (Figure 3-5). The PLP contractor reported the sludge material in the pond appeared to be paint waste, petroleum products, and resins. They observed different multicolored layers in the material, possibly representing different periods of dumping the various wastes. The depth of the material was estimated to be about 4 feet with a total volume estimate of between 65 and 70 cubic yards.

The PLP contractor collected four samples from the pond sludge, using a hand auger, which were combined into one composite for analysis. The samples were collected at 1 foot, 2 foot, 3 foot and 4 foot depths. They observed a 1 to 2 second spike of 500 to 700 ppm on an organic vapor analyzer (OVA) when the soil was disturbed.

The PLP contractor reported detecting the following VOCs in the pond sludge; methylene chloride (1,690 ppm), trichlorofluoromethane (299 ppm), 1,1,2-trichlorotrifluoroethane (216 ppm), 1,1,1-trichloroethane (317 ppm), trichloroethene (1,530 ppm), toluene (141 ppm), ethylbenzene (270 ppm), and total xylenes (1,320 ppm). In addition, the sludge contained 67,000 ppm total petroleum hydrocarbons (TPH), and 4.9 ppm of PCBs (Arochlor 1254). Analysis for

RCRA TCLP metals was reportedly negative except for lead. The PLP contractor report indicated detecting lead at 0.84 ppm. It is unclear from their report whether this was a total metals analysis measured in mg/kg, or a leach procedure measured in mg/L. In either case the concentration detected is less than the DW designation limit for lead of 5 mg/L.

Golder (1992b) reported that concentrations of methylene chloride, trichlorethene and PCBs detected in the pond sludge exceed MTCA Method B soil cleanup levels. For TPH, the concentration detected in the sludge exceeds the Method A number for TPH (other) of 200 mg/kg, which is based on protection of groundwater. Ethylbenzene, toluene and xylenes would also exceed the soil cleanup standards based on 100 times the groundwater cleanup standards.

Chemical data for the pond sludge are presented further in Chapter 5 and incorporated into the overall chemical data evaluation performed as part of this RI.

3.2.3 Results of the Rogers Trench Geophysical Survey

As described in Section 2.6.1, a magnetometer survey was performed as part of this RI along the central axis of the Rogers Seam from north of the mine yard at Highway 516 to the S.E. Summit-Landsburg Rd. The location of the survey is shown in Figure 2-7. This survey was performed to identify areas along the seam that may contain ferrous metallic debris. This ferrous debris would potentially include drums or other metallic objects associated with prior waste disposal.

Total field data for the top and bottom sensor, and the vertical gradient data were plotted in profile form. The anomalous zones for each of these data were in general agreement. There is a greater variation, however, in the baseline values of the total field data compared to the vertical gradient data. This variability is interpreted as the effects of topography and diurnal variations on the total field that do not effect the vertical gradient. For this reason, the vertical gradient is considered a more reliable indicator of debris locations. The vertical gradient data are therefore shown in Figure 3-6 and used for the following interpretations. Figure 3-6 shows the vertical gradient data superimposed on a site base sheet. Annotations made by the field operators are indicated on the figure to assist in data interpretation.

The vertical gradient profile shown in Figure 3-6 can be divided into two zones. One zone from 0+00 to 23+80 is relatively free of anomalies while a second zone from 23+80 to the end of the profile contains many anomalies. Anomolies are interpreted to represent possible waste sources (i.e. drums). This is consistent with the current understanding of the waste disposal history at the site in which dumping is believed to have been confined to the northern portion of the trench.

<u>Zone 1</u>

Within the first zone, from about 00+00 to 11+00, the vertical gradient is relatively constant with only minor variations about zero. Based on this response and the absence of any surface debris, this area is interpreted to be free of ferrous metallic debris.

A small anomaly at approximately 11+00 is located at the base of one of the surface depressions with no visible surface debris. Because the anomaly is only one reading with small magnitude, it is not considered a significant concentration of debris.

From about 12+10 to 16+00 a series of small to moderate anomolies exist. The largest reading is due to an old clothes dryer. Several small mounds and two tires with hubs were also identified. The anomolies are of low to moderate magnitude and can probably be accounted for by the small amount of domestic debris seen on the surface and a minor amount of additional debris at shallow depth.

Two small anomolies near 18+00 and 19+20 are due to the magnetometer sensors being within 5 ft of the rock wall at these locations. From these points to about 23+80 the vertical gradient shows no anomolies and this area is interpreted to be free of ferrous debris.

Zone 2

The area from about 23+80 to 29+00 contains a concentration of large magnitude anomolies. Within this area there is various domestic and demolition debris (e.g. domestic garbage, refrigerator, sheet metal, wood debris) visible on the surface. Based on the high density and magnitude of the anomolies, there is probably a significant concentration of ferrous debris located below the surface. This area corresponds approximately to the “Area 1b” designated in the drum removal project report (Landsburg PLP Steering Committee 1991). A large anomoly from 30+30 to 31+30 corresponds to a backfilled saddle in the surface depression. In addition, the east edge of the surface depression from 31+00 to 31+30 has the appearance of a ramp used for dumping. The surficial evidence and the large magnitude of the magnetic anomolies suggest a significant concentration of ferrous debris.

A single point anomoly with a large magnitude is seen at about 33+00. This reading represents the only reading obtained near the base of a dumping area that is now covered with a black plastic tarp. The area from about 32+40 to 33+00 was not accessible due to topography. The high gradient seen near 33+00 does suggest that ferrous objects probably do exist at the base of the black plastic tarp.

The area from about 33+20 to 37+00 contains no significant anomolies and is considered free of any detectable concentration of ferrous objects. A few household garbage bags and a pile of old tires were found but no metallic debris was observed in this area.

The area from about 37+00 to 40+70 contains a large number of high magnitude anomalies, including two drums in the vicinity of 37+70. Demolition debris, wood debris, and some small metallic objects were observed throughout the area. From about 38+80 to 40+70 the west side of the trench has been reworked and backfilled. The large concentration and magnitude of the magnetic anomolies and the evidence of the debris at the surface suggest there is probably a significant concentration of ferrous debris buried in this area of the trench. This area corresponds roughly to the “Area 2” designated in the drum removal project report (Landsburg PLP Steering Committee 1991).

The area from about 40+70 to 45+20 does not contain any anomolies and is considered free of any detectable concentrations of ferrous debris.

The area from about 45+20 to 48+50 contains several anomalies with moderate magnitude. This area covers the last surface depression before the S.E. Summit-Landsburg Rd. A small amount of domestic debris, including some metallic objects, was observed throughout the area and can probably account for some of the anomolies. The number of anomalies suggests there is possibly a moderate amount of additional ferrous debris below the ground surface. The probability of the debris being domestic refuse from the general public is greater due to the close proximity of this area to the S.E. Summit-Landsburg Rd. and the easy access to the area. In addition, the area was reportedly surface mined for coal due to the proximity of the coal to the surface in this area of the site. Mine spoils back-filled into the excavation may also account for the observed anomalies.

Therefore, the results of the magnetometer survey work performed in the trench appear to confirm the prior understanding regarding the locations of potential waste materials in the trench. Dumping does not appear to have occurred in the southern half of the trench consistent with observations made in Ecology and Environment (1991) and Landsburg PLP Steering Committee (1991). In the northern half, there is the possibility that additional waste materials occur at some depth beneath the base of the trench. These materials are located in the areas where dumping is thought to have taken place in the past, namely the Areas 1 and 2 designated in the drum removal work (Figure 3-5) (Landsburg PLP Steering Committee 1991) and areas A, B & C designated in the SHA (Figure 3-4)(E&E 1991). These areas which may potentially contain waste materials buried beneath the surface are depicted in Figure 3-6.

3.3 Geological Characteristics

This section describes the geologic characteristics of the site and region. The region consists of a loosely defined area encompassing the south-central portion of King Co. The regional geology is based primarily on geologic mapping of the Cumberland quadrangle (Gower and Wanek 1963) and the Hobart and Maple Valley quadrangles (Vine 1962), as well as work by Luzier (1969). Site specific details were obtained from mine records and plans obtained from Palmer Coking Coal Company, driller's logs of Study Area wells on file with Ecology, and the borehole drilling conducted as part of this RI. Figure 3-7 depicts the generalized surficial geology in the Study Area vicinity.

3.3.1 Regional Geology

The Landsburg Mine site Study Area is located along the eastern margin of the Puget Sound Lowland, a broad, gently rolling glacial drift plain whose surface is commonly about 400 to 600 ft above mean sea level. In the vicinity of the Study Area, the lowland merges eastward with the glaciated foothills of the Cascade Range. The foothills are protruding parts of a Tertiary bedrock surface that descends westward beneath thick deposits of Quaternary age. Rocks of Tertiary age in the vicinity of the Study Area include sedimentary and volcanic rocks of the Puget Group (Tp), intrusive igneous rocks (Ti), and andesitic volcanic rocks (Ta). The thickness of these rocks is not known with certainty but may be on the order of several thousand feet. Of these, the Puget Group rocks are of primary relevance to this Study Area.

3.3.1.1 Stratigraphy

Puget Group (Tp) Bedrock

The oldest rocks exposed in the region vicinity are the nonmarine coal-bearing volcanic and sedimentary rocks of the Tertiary-aged Puget Group (Tp) (Gower and Wanek 1963). Beginning about 55 million years ago in the Eocene epoch of the Tertiary, these materials were deposited in a broad coastal plain which existed in the present position of the Cascade Range and Puget Sound Lowland. Great thickness of arkosic sediments derived from the North American continental plate to the east accumulated in the plain. Volcanic rocks and sediments derived from volcanoes were occasionally interbedded with the arkosic sediments, along with extensive swamp deposits formed under a sub-tropical climate. Toward the end of Eocene time, the source of the arkosic sediment was cut off from the coastal plain, probably by volcanic activity and uplift in the present position of the Cascade Range. Over time and through compaction at depth, these sediments were lithified into the sandstones, siltstones, shale and coal of the Puget Group. In middle or late Miocene time, most of the Tertiary formations of western Washington were extensively folded and faulted as a result of tectonic forces occurring along the continental margin.

The Puget Group is composed of sandstone and siltstone with numerous carbonaceous shale and coal beds and minor amounts of claystone and conglomerate. All gradations between sandstone and siltstone are present, and most of the rocks are either silty sandstone or sandy siltstone. The sandstone beds are typically yellowish gray to light olive gray, fine grained, micaceous, and arkosic or feldspathic. Most of the sandstone beds are cross-laminated and form massive outcrops. Some beds are ripple marked, and convolute bedding and intraformational breccia occur in a few places. The siltstone beds commonly are medium light gray to dark gray and contain varying amounts of finely disseminated carbonaceous fragments (Gower and Wanek 1963). The Landsburg Mine coal seams and associated shales and sandstones are within the Puget Group.

Excellent exposures of Puget Group rocks occur in the canyon of the Green River, where a 6000 ft thick section is exposed. Neither the base nor the top of the Puget Group is exposed in this section. The aggregate thickness of the Puget Group rocks is felt to approach nearly 11,000 ft locally (Vine 1962).

In the Tiger Mountain-Taylor Mountain area, about 8 miles north of the Study Area, Vine (1962) has sub-divided the Puget Group into the Tiger Mountain, Tukwila, and Renton Formations. The Tiger Mountain Formation consists of nearly 2,000 ft of a medium grained arkosic and feldspathic micaceous sandstone. The upper part is interstratified with the overlying volcanic rocks of the Tukwila Formation. A zone of carbonaceous shale and coal occurs, at least locally, near the top of the lower main body of the Tiger Mountain Formation. The Tukwila Formation consists of andesitic volcanic rocks about 7,000 ft thick. Epiclastic volcanic sandstone, tuffaceous siltstone, tuff-breccia, volcanic conglomerate, and thin vesicular lava flows or sills compose the bulk of the Tukwila Formation. The Renton Formation is the youngest formation recognized in the Puget Group and is comprised of arkosic and feldspathic micaceous sandstone, siltstone, carbonaceous claystone and coal, as much as 2,250 ft thick.

With respect to the Study Area, fossil leaves collected at a locality between the Landsburg and Rogers Seams were identified in Wolfe et al. (1961) as of probable middle Eocene age. The Puget Group rocks exposed in the Study Area, therefore, are probably of pre-Tukwila age and may be equivalent to a part of the lower main body of the Tiger Mountain Formation.

The upper part of the Puget Group intertongues with the base of the overlying andesitic volcanic rocks (Ta), a heterogeneous assemblage of late Eocene- to early Oligicene-aged volcanic and volcanic sedimentary rocks. In the Study Area vicinity, however, these rocks are essentially absent and occur only in small, isolated outcrops. The igneous intrusives (Ti) are poryphyritic andesite sills ranging in thickness from 5 to 100 ft. These rocks are similar in composition and are presumably related to the andesitic volcanic rocks that overlie the Puget Group. Igneous rocks (Ti) intrude the Puget Group in the Cumberland and Hobart quadrangles, however, none are present in the vicinity of the Study Area (Figure 3-7).

Glacial Drift (Qvt, Qvr, Qva, Qvi)

Cyclic cooling and warming periods during the Pleistocene resulted in alternating glacial and interglacial periods in the Puget Sound Region. There is evidence of at least four advances of a vast and thick ice sheet which flowed south from British Columbia, reaching its maximum extent in southern Thurston County. During the most recent glacial stage, the Vashon, which occurred some 13,500 to 15,000 years ago, ice thickness reached 3,000 ft near Renton, 2000 ft over Tacoma, and at least 1,500 ft near Black Diamond along the mountain front (Luzier 1969).

Most of the surface in the Study Area vicinity is thickly mantled by deposits associated with the Vashon glacial episode (Figure 3-7). During advance of the Vashon ice sheet, unconsolidated deposits beneath the ice were compacted and the land surface mantled by till laid down at the base of the ice sheet as it passed over the landscape. During recession, melting ice lobes produced large quantities of melt water which released stratified outwash. Locally, other deposits representing one or more of the older drift sheets may also be present below the Vashon drift. These are observed (Pre-Vashon drift - Qu) in exposures in the Cedar River Valley as till, fluvial sand and gravel, lacustrine sand, silt, clay and peat (Figure 3-7).

Vashon drift in the Study Area vicinity consists mostly of recessional outwash (Qvr) and till (Qvt) with some minor occurrences of advance outwash (Qva) and ice-contact deposits (Qvi) (Vine 1962; Luzier 1969). The outwash deposits are composed of stratified gravel, sand, silt, and clay and are confined largely to the lowlands areas, where locally they may exceed thicknesses of 250 ft. Thicknesses are generally less than 100 ft (Gower and Wanek 1963; Luzier 1969). Recessional outwash (Qvr) is comprised of a well-sorted sand and pebble-cobble deposited chiefly as an outwash plain. Till (Qvt), which also occurs in the lowlands but most commonly mantles the hillsides, consists of a compact mixture of gravel and occasional boulders in a clayey, silty sand matrix. In appearance, till is somewhat like concrete. Thickness is generally 10 to more than 50 ft. As seen in Figure 3-7, till mantles the hills of Tertiary bedrock comprising much of the Study Area while recessional outwash fills in the lowland areas around the perimeter of the Study Area boundaries.

Ice-contact deposits (Qvi), which consist of silty sand and pebble-cobble gravel, were deposited chiefly as kames and kame terraces. These may include large boulders, lenses of till, and lenses of silt and clay. The material is characterized by abrupt changes in grain size, degree of sorting, and stratification. An extensive area of ice-contact deposits is located to the southwest of the Study Area near Retreat Lake (Figure 3-7).

Peat and Swamp Deposits (Qp)

Peat and swamp deposits are scattered over the surface of the glacial drift. Several occur in the Study Area vicinity (Figure 3-7). These consist mainly of peat and muck deposited in areas of closed or poorly drained depressions in the glacial drift, and include silt and clay. Thickness of the material is generally less than 25 ft. Several isolated occurrences of this material are mapped around the perimeter of Study Area boundary (Figure 3-7).

Alluvium (Qua)

Alluvial deposits of gravel, sand, and silt occur along all the large streams and rivers. These deposits include modern alluvium in the river channel in river valleys and the bordering low-lying terraces. Only those deposits along the Cedar River are extensive enough to be identified on the geological map (Figure 3-7).

3.3.1.2 Structure

Throughout most of the mapped area, the early Tertiary rocks are highly folded and faulted. In the Cumberland quadrangle the major period of deformation is assumed to have occurred during Miocene time. Only gentle warping occurred after the deposition of the late Miocene sediments (Gower and Wanek 1963).

Folds

Bedrock in the Study Area vicinity has been extensively folded into a series of north and northeast-trending folds (Gower and Wanek 1963). Most of these structures are south-plunging asymmetric folds with east-dipping axial planes. The strata most commonly dip 50° to 70° on the steeper limbs and 25° to 50° degrees on the opposite limbs.

Faults

The rocks in the study area have been displaced by numerous faults. Strike-slip, normal and high angle reverse faults have been recognized, but the type of movement along most of the faults is unknown (Gower and Wanek 1963). Thrust faults are anticipated to be present in the region (Zoback and Zoback 1980). Most faults in the region trend northwest, and the majority are apparently down thrown on the northeast side (Gower and Wanek 1963). Displacement ranges from a few inches to as much as several thousand feet.

Stress

Regional stress directions are useful for understanding local fault systems. The Puget Sound - Olympic Peninsula province is characterized with the major principal horizontal stress being a north-south compression. The minor principal horizontal stress direction throughout this province averages about east-west (Zoback and Zoback 1980). While local perturbations may exist, on a regional basis faults that are steeply dipping with east-west strikes (across the coal seams in the Study Area) should therefore be tight due to the north-south compression.

3.3.2 Site Geology

3.3.2.1 Stratigraphy

Geologic cross-sections depicting the stratigraphy of the Study Area are shown in Figures 3-8 through 3-13. Figure 3-8 depicts the cross-section locations. Figure 3-9 is a section orientated along strike of the Rogers coal seam while Figures 3-10, -11 and -12 are drawn perpendicular to the seam. A detailed depiction of the stratigraphy in the immediate vicinity of the Rogers Seam is shown in Figure 3-13. These cross-sections are based on the geologic mapping of Luzier (1969), shown in Figure 3-7, mine construction records and drawings, well logs of private wells in the area, and the borehole drilling conducted as part of monitoring well installation activities. Borehole and well construction logs and test pit logs for boreholes and test pits completed as part of this RI are shown in Appendix E. Photographs of cores obtained during drilling are shown in Appendix D.

The stratigraphy of the site, as observed during drilling activities, is generally consistent with the description presented above in Section 3.3.1 for the region, and generally conforms to the conceptual model of site geology described in Golder (1992b). Site stratigraphy consists of a thick sequence of folded Tertiary bedrock of the Puget Group mantled by glacial drift of the Vashon (and possibly Pre-Vashon) glacial stage.

Puget Group

Puget Group rocks encountered at the site consist of interbedded siltstone, sandstone, shale and coal. These materials are typically fine-grained, unweathered, and yellowish brown in color. Except for the coal, which is typically very weak and friable, these materials are generally medium strong to strong and well-cemented. The depth to these rocks varies from near 0 ft at the higher elevations to in excess of 100 ft at lower elevations where thicker sequences of Quaternary deposits have accumulated. The base of the Puget Group was not encountered during drilling as the thickness of the material is expected to be on the order of several thousand feet.

A typical east-west section through the Rogers Seam is shown in Figure 3-13. On the east side of the seam is a massive sandstone bed and one foot thick layer of shale. The coal seam itself is approximately ten ft in thickness. On the west side is a five to eight ft thick carbonaceous shale and a massive sandstone (Eltz 1992). The thickness of the individual beds, as seen in the test pit logs (Figures F-8 to F-10), varies from a few feet to 10s of feet.

Glacial Drift

The glacial drift materials at the site are comprised primarily of till and recessional outwash. Minor occurrences of advance outwash and ice-contact deposits also occur near the Study Area but are of little significance to the site itself. Recent alluvium is confined to the stream and river channels of the Cedar River, and possibly Rock Creek. Isolated swamp deposits, consisting of peat and lacustrine muds, are scattered about the perimeter of the Study Area.

The till consists of a compact mixture of gravel in a clayey, silty sand matrix. Recessional outwash is comprised of a well-sorted mixture of sand and gravel. Till mantles the hillsides and recessional outwash generally fills in the lowlands. Additional till may occur below the outwash deposits. The till may possibly overlie deposits of Pre-Vashon age which may be present atop the bedrock.

The total thickness of the glacial deposits ranges from near 0 ft near the hilltops to possibly in excess of 100 ft in the lowland areas and stream channels. In most areas of the site itself, the thickness of the drift is probably between about 10 to 50 ft. In the shallow depression formed between the two primary hills at the site, however, the thickness of glacial drift deposits apparently exceeds 100 ft (Figure 3-11).

3.3.2.2 Structure

Folds

The site and Study Area are situated over the western limb of a northeast trending anticline. Puget Group strata dip steeply with dip angles of the Rogers coal seam and adjacent strata near 90 degrees on the north end of the site and 63 degrees at the south end of the mine (Figure 3-14).

Faults

Several faults were encountered during mining of the Rogers coal seam and were documented on the mine superintendents drawings. Figure 3-9 illustrates the location and trace of faults observed during mining operations.

Most noteworthy is the fault in the northern portion of the mine where approximately 75 feet of displacement (PCC 1992) required a 130 ft long rock tunnel to reconnect mining operations to the coal seam. This was the only mapped fault which resulted in complete loss of the coal seam. The fault extends vertically through all four levels of the Rogers Mine to land surface where the unmined and hence uncollapsed rock pillar is used for the trench cross-over roadway. This fault also appears to have been encountered when mining the Landsburg seam some 750 ft east of the Rogers Seam (Falk 1992); the location of this contact indicates that the fault strikes approximately east-west. Records from the mining operations on the adjacent Frazier seam also have indications that a fault displacement may have been encountered close to the eastward extension of this same fault observed in the Rogers and Landsburg seams.

Mine records were reviewed to determine the characteristics of the fault, such as the nature and extent of any gouge present. Review of mine inspector's reports, mine drawings and the mine superintendent's map for the periods when the rock tunnel was being constructed have found no reference to fault gouge. In addition, there is no indication of the need for ground support in the rock tunnel that would undoubtedly be required if weak zones were encountered. The absence of the information leads to the conclusion that the disturbed/altered zone is very narrow. The conclusion is consistent with interviews with retired mine personnel regarding the lack of water when mining through this fault (Simmons 1992).

Pertinent features of the smaller faults include; offsets of from 2-to-16 ft (Mine Superintendent's Drawings); polished surfaces (Eltz 1992); and tightness (reports by all interviewed personnel that mining through fault zones did not result in increased water flow).

In addition to these faults observed during mining, the geologic map for the area (Figure 3-7) depicts an apparent reverse fault located at the southern end of the mine site and extending towards Georgetown to the southeast. The fault occurs just to the south of the mined portion of the Rogers Seam. No mention of the fault is noted in mine records. The fault has been observed in the Ravensdale No. 5 coal bed located just south of Georgetown (Gower and Wanek 1963). The trace of the fault has been inferred to the Landsburg Mine area to explain the apparent offset of the Ravensdale coal beds from the Landsburg coal beds. The two series of coal seams are presumably correlated. The inferred trace of the fault results in a northwesterly trend. The fault apparently truncates the Landsburg coal seams where they intercept the fault (Gower and Wanek 1963). The northern side is indicated as the downthrown side. It is speculated that this fault may be a continuation of the Green River fault, a major fault in the eastern portion of the Cumberland quadrangle which has resulted in significant movement along the contact between the Puget Group and overlying andesitic volcanic rocks.

Joints

Joints were observed in the exposed sandstones along both the hanging and foot walls within the trench of the Rogers Seam during site reconnaissance by GAI. The joints were minor and appeared tight. Two sets of joints were observed which appeared perpendicular to each other in the exposure. Joints within each set had a spacing of approximately three feet. The strike of these joint sets are expected to be parallel to site faults. The reviewed literature and data did not provide information on jointing in the study area.

3.4 Site Mining Related Characteristics

This section of the report describes the history of mining at the Landsburg Mine site, provides details on coal characteristics and quality, and addresses the stability of the remaining trench.

3.4.1 Mining History

Historical data, pertinent to the Landsburg Mine site, was collected from a variety of sources, including:

1. Records from the Washington State Division of Natural Resources (DNR), including:

- Mine Map Collection, File K55, Landsburg and Rogers Mines.
- Structural Geology maps.
- Open File Reports on coal mining in King County.
- Annual Report of Coal Mines (1959 - 1962)
- Seattle Water Department, Cedar River Wellfield reports.

2. Records held by the Palmer Coking Coal Company, including:

   - Daily Mine Safety inspections and Reports: The daily mine inspection reports indicate that methane was never detected in any of the Rogers Seam mines. Carbon monoxide was occasionally detected along with depleted oxygen conditions indicating that spontaneous combustion, a precursor to mine fires, was occurring.

   - Annual Production Reports: Data from these reports has been used to construct mine raw coal and clean coal production estimates.

   - USBM Coal Mine Inspection Reports: These reports describe the conditions in the operating mines and include reference to roof control plans and mining methods.

   - Coal Analysis Reports: These reports contain the results of laboratory tests that were carried out to determine the moisture, ash, carbon, sulfur and other volatile matter content and BTU values for Rogers Seam coal samples.

3. Interviews with retired mining personnel, including:

   - Mr. Jack Morris, President of PCC during Rogers mine(s) operations.
   - Mr. Evan Morris, Vice President of PCC during Rogers mine(s) operations.
   - Mr. Carl Falk, Secretary of PCC during Rogers mine(s) operations.
   - Mr. Archie Eltz, Miner at Rogers mine(s).
   - Mr. Cameron Rich, Engineer for Rogers mine(s).
   - Mr. Alva "Bud" Simmons, Mine Superintendent, Rogers mine(s).

Three operating mines have been documented in the Mine Inspectors Reports for the Rogers Seam:

- Rogers Mine: Operated from 1959 to 1962 from the Rogers No.1 slope.
- Rogers No.2: Operated from 1960 to 1966 from the Rogers No.2 slope.
- Rogers No.3: Operated from 1963 to 1975 from the Rogers No.3 slope.

Two other underground mines were operated adjacent to the property in the Landsburg seam to the east and in the Frazier seam to the west (see Figure 3-2); summary information for mines operated in these three seams is presented below.

3.4.1.1 General Description

Frasier Seam The Frasier seam, located to the west of the Rogers Seam, was mined intermittently from the late 1800s to the mid 1940s. A small section of the north end of the Frasier was strip mined in the 1970s. The 1946 map of the Danville mine (in the Upper Frasier seam) workings indicated the presence of a tunnel that drained water to the northern end of the mine (adjacent to pipeline road). The entrance to this tunnel has collapsed but still provides egress for groundwater. Several other shafts and slopes provided access to the Frasier seam workings but were not locatable during site reconnaissance.

Landsburg Seam The Landsburg seam, located to the east of the Rogers Seam, actually consists of the three separate seams (18 ft, 10 ft, and 6 ft seams). The northern end of the underground mine was worked between the 1930s and 1940s. The southern end was worked from the late 1940s until about 1960. The last mining activity was a stripping operation at the southern end of the mine that was completed in 1977. Slope accesses to the Landsburg seam mines, located to the north (adjacent to pipeline road), were not located during site reconnaissance.

Rogers Seam The Rogers Seam was discovered in the late 1950's when a bulldozer, prospecting for coal, cut across the strata with a minimum of cover; the bulldozer operator's name was Enoch Rogers and the seam was named in his honor. The Rogers Seam was mined from four (4) different levels accessed from three (3) slopes/declines as shown on Figures 3-2 and 3-9; a "water level" tunnel was also constructed to facilitate water removal from the upper level. The seam was mined from 1959 until 1975 when all active mine openings were closed by blasting. During this time frame, approximately 490,000 tons of clean coal were produced.

The steep inclination of the coal seam led to the use of mining methods typically associated with the hardrock mining industry and associated terminology. For example, in this mine, the mine roof is referred to as the "hanging wall" and the mine floor is termed the "foot wall"; other terminology definitions are provided below.

3.4.1.2 Coal Seam Characteristics

As discussed above in Section 3.3, the Rogers Seam strikes approximately northeast-southwest and dips from between 90° at the north end near the Cedar River to about 70° at the southern limit. A typical east-west section through the seam (Figure 3-13) locates a massive sandstone footwall, one foot shale, four (4) feet bottom coal, two (2) feet muck, four (4) feet top coal, four to seven (4 to 7) feet carbonaceous shale and shale, and a massive sandstone hanging wall (Eltz 1992). “Muck” consists of a carbonaceous shale.

Coal analysis results (see Table 3-1) indicate that the Rogers Seam coal contains up to 65 percent carbon, from 5-15 percent ash, and one half percent sulphur. The sulphur content is typical of Washington coals which are reported to range from about .4 to 1.1% (Fuste et al. 1983). The coal is classified as high volatile bituminous with a calorific value of between 10,500 and 13,000 BTU/lb.

3.4.1.3 Mining Method

Due to the vertical orientation of the coal seam, the Rogers mines utilized a system of coal extraction more typically used in the hardrock mining industry. This system involved the development of "levels" with coal extracted by "booming" between underlying and overlying levels.

The initial development work involved constructing both an access slope and a return-airway slope from the surface to the mine level. Once the exhausting ventilation circuit was established, a level entry or "gangway" and "counter" were advanced along strike to the mine limit (either property boundary, fault, or other location determined by mine management). The gangway was driven at an upward slope of approximately 3% to promote drainage back to the access slope where a small sump was located to facilitate water handling. Gangways were typically mined 14 -to- 16 ft wide by 10 ft high with a 10 ft by 10 ft counter mined approximately 30 ft above. Vertical chutes, approximately 9 feet wide, were driven between the gangway and counter on 50-to-75 ft centers. All excavation was by drill and blasting off the solid, however, in later years, a vertical kerf cutter (large chain saw) was used to mine a relieving slot prior to drilling blast holes. Ground support consisted of wooden sets (two 16-to-24 inch diameter, upright timber posts with a 16-to-24 inch diameter, timber crossbar) on seven (7) feet centers with 2 x 4 inch wooden lagging between sets. Coal was loaded into 5-ton mine cars and hauled to the slope bottom by an electric locomotive and from there to the surface by continuous rope haulage using a large surface hoist.

Once the selected boundary was reached, the zone above the counter was developed ready for "booming". This process involved additional chutes mined upwards and crosscuts mined parallel to the counter on approximately 30 ft centers. The uppermost crosscut was located to leave 50-to-75 ft of coal between the crosscut and overlying gangway or surface. Four (4) inch boreholes were typically drilled upwards from the top crosscut in levels 2 and 3 to drain water from the overlying workings.

A majority of the coal mined from the Rogers mines was extracted by "Booming". This mining term, unique to mines in the Landsburg, Rogers, and Frazier seams, simply refers to the process of blasting pillars of coal isolated between adjacent crosscuts/entries and chutes. The booming round (see Figure 3-13) was initially fired in the uppermost pillar to start the cave. Coal was then "pulled/drawn" through the first open chute and loaded into mine cars. Pillar booming then proceeded downwards towards the gangway where part of the pillar between the gangway and counter was occasionally left due to poor conditions. Pillar booming then proceeded back towards the slope allowing for concurrent booming and crosscut/chute development.

There is some disagreement between the retired Palmer Coking Coal personnel interviewed regarding whether blast holes were drilled only in the coal or into both the coal and hanging wall rock. A section of the booming round, drawn in 1963 after a cave from the 2nd level ran through to the surface gravels in the southern end of the mine, indicates that holes were drilled to within about two (2) feet of the hanging wall. This round would result in a caving width of about 14 -to- 16 ft consistent with the width reported by personnel who worked underground (Eltz 1992; Simmons 1992).

In the upper level, booming typically resulted in a cave to surface and coal was drawn down until the miners could see daylight (Simmons 1992; Eltz 1992). This process caused short circuiting of the ventilation system requiring that the caved area be periodically backfilled from the surface (Simmons 1992). In the 2nd and subsequent levels, blastholes were drilled to within a few feet of the overlying level gangway thus connecting with the overlying caved zone. Coal was subsequently drawn down until rock and/or gravel appeared in the gangway. The rock, being heavier than the coal, would often work its way to the bottom (loading area) first, presenting mine management with the dilemma of whether to load out the rock in order to recover additional coal. One miner reported seeing daylight from the third level (Eltz 1992), however, this phenomena was not confirmed by other underground personnel. Observation of the caved zone from the upper crosscut in the level being mined indicated that the caving area was full of broken material confirming that material was being drawn from the level above.

3.4.1.4 Mine Layout and Sequencing

Details of the mine layout and sequencing of mining operations are based on maps and working drawings retrieved from Palmer Coking Coal and the Washington Division of Natural Resources (Table 3-2) supplemented by Mine Inspectors Reports and personnel interviews. Key elements of the sequence of operations in each of the three Rogers mines are shown in Tables 3-3, 3-4, and 3-5.

The Rogers No. 1 (referred to in the records only as the "Rogers Mine") Slope was constructed prior to 1959 and was then abandoned due to the presence of a fault. The slope was re-entered in March, 1959 and a 130 ft long rock tunnel was driven to the south to intersect the coal seam. A return air slope was subsequently completed and a gangway and counter were driven to the southern boundary of the upper level by January of 1960. Rogers No. 2 access and return air slopes were completed in 1960 while coal was being boomed from the 1st level; coal extraction in the 1st level was completed in 1962.

Mining of the 2nd level gangway and counter was completed in December, 1961 and the Rogers No. 3 slope was driven from the 2nd level to the surface during 1962. Pillar recovery ("booming") was completed in the second level in June of 1965. The 3rd level gangway and counter were driven, concurrent with 2nd level booming, starting in January of 1964. These entries were mined a distance of approximately 4950 ft from the Rogers No. 3 slope to the northern property line and were completed in May, 1966.

Although no precise dates are provided on the mine drawings, the water level tunnel and counter were constructed and coal was "boomed" to the base of the overlying "strip pit" between 1965 and 1966, based on an examination of sequential mine drawings. From November, 1966 to July, 1967 coal was removed from beneath the Rogers No. 2 Slope portal to a point located 300 ft to the north. This area, initially covered by about 13 ft of gravel, is shown as extensively caved on the mine superintendent's drawings. In addition, based on a reference in Coal Mine Inspectors Report No. A23 and the interview with Archie Eltz (Eltz 1992), it is suspected that the excavation may have daylighted in this area. Photographs supplied by Palmer Coking Coal Company (PCC 1992) also indicate the presence of caved areas and that coal was surface mined in this area during 1975.

Completion of the Rogers No. 3 Slope to the fourth level and construction of the 4th level gangway and counter also commenced in July of 1967. Fourth level development and 3rd level booming continued through September of 1969 when the 4th level gangway and counter were completed. This area was then left open until booming of the 3rd level to within 250 ft of the Rogers No. 3 slope was completed in June of 1970. Significant floor heave was encountered on returning to the fourth level requiring additional excavation. Additional crosscuts and chutes were also constructed prior to firing the first 4th level boom in September, 1970. It should be noted at this point that the area in the 3rd level, immediately above the first two booming rounds in the 4th level, was not extracted due to collapse of the hanging wall in the upper 3rd level crosscut. It is therefore likely that the first two 4th level booming rounds only caved as far as the 3rd level gangway.

Booming was completed in the 4th level in October, 1974. Pillars adjacent to the Rogers No. 3 slope were extracted during the following year and the Rogers No. 3 mine was abandoned in August of 1975. The mine was permanently closed on December 12, 1975 by blasting in the access and return air slope portals. A bulldozer regraded the surface to its present generally level topography.

3.4.1.5 Coal Production and Extraction Ratio

Coal production data obtained from Palmer Coking Coal Co. (PCC), Division of Natural Resources (DNR), and the State's Annual Report of Coal Mines have been summarized and presented in Table 3-6. A total of approximately 890,000 tons of raw coal was produced during the life of the three mines resulting in about 494,000 tons of clean coal.

Extraction ratios were estimated using the following steps:

(1) Coal in place was estimated by measuring the sectional area of the extraction zone in each mine and multiplying by the reported coal thickness.

(2) The extracted coal volume was estimated using the clean coal tonnages and a coal density of 67 lb/ft^3.

(3) The extraction ratio was estimated by dividing the extracted volume by the in place volume.

This simplified analysis provides an average extraction ratio of about 80% for the Rogers Seam and individual level estimates of 62% Rogers No. 1, 69% Rogers No. 2 and 90% Rogers No. 3.

3.4.1.6 Water Inflow and Pumping Data

Groundwater control was accomplished in the Rogers mine(s) by grading the gangway at a slight incline with positive drainage back towards the bottom of the mine access slope. Water gravity drained, via a shallow ditch dug in the footwall, to a small sump at the slope bottom and was pumped, from there, out of the mine.

Two types of pumps were typically used for water removal. Centrifugal pumps were used when larger than usual pumping rates were required due to water accumulation following a power failure. These pumps were characteristically low head, high volume and had to be used in stages (e.g., water was first pumped from the 3rd level to the 4th, from there to the 2nd and so on). The type of pump most frequently used for routine mine dewatering was the Bean pump; one large Bean (Model 345) with a maximum rating of 80 gpm and two smaller Beans (Model 55) with a combined capacity of about 60 gpm. The Bean pumps were typically located in a cut out between the gangway and counter with suction lines deployed to the sump; the big pump was typically run continuously even when there was no water in the sump. A Bean pump is a piston pump as opposed to the centrifugal pumps used for large volumes.

It is difficult to precisely estimate the quantity of water entering and pumped from the Rogers mine(s) as, consistent with standard practice, pumping records were not kept. However, an approximate range in inflow rates can be estimated based on mine personnel estimates and notes on mine maps, back-analysis of water accumulations observed during power outages and pump capacity/utilization.

The first source of inflow rate data is an interview with Mr. Bud Simmons (Simmons 1992) who estimated a pumping rate of 35 to 40 gpm. He also noted that the mine was typically dry in the summer months and this is confirmed by a note on the 1963 mine map which states, "Very little water being made. Pumped 1/2 hour each week during summer and fall prior to winter and rainy season". This note references water removal from the bottom of the Rogers No.1 slope during mining of the 2nd level at the southern end of the mine. This would indicate that the primary source of inflows into the mine was direct infiltration of rainfall. As noted earlier, faults were generally reported as tight and did not produce significant quantities of water.

The second estimate is based on telephone interviews with Mr. Bud Simmons and Mr. Bob Morris. Mr. Simmons reported that power outages of from 3-to-4 hours typically resulted in water rising in the gangway a distance of 1-to-2 feet. Mr. Morris remembered a situation between 1972 and 1975 when power was out for 24 hours and resulted in a rise in water level of about five (5) feet. Back-calculation of these two events provides inflow estimates of 36 gpm (Morris) and 35 gpm (Simmons).

It is therefore appropriate to state a range in probable inflow rates with qualifying assumptions:

Min. Expected Value for Pumping Rate:	20 gpm.
Most Likely Value for Pumping Rate:	35 gpm (calculated for wet season).
Max. Expected Value for Pumping Rate:	80 gpm (capacity of large Bean pump).

3.4.2 Remnant Condition of the Rogers Seam, Underground Workings and Surface Site

Coal extraction in this near vertical coal seam, and associated caving at the outcrop, has produced an intermittent trench up to 100 feet wide and 70 feet deep (see Figure 3-1 and 3-3). The walls of the trench are typically steep sided and composed of massive sandstone. However, in some areas (e.g., north of the rock bridge), the sandstone bed forming the eastern side of the trench (mine footwall) has failed exposing the shale material behind. Areas where the shale has been exposed are not as steep as those where the sandstone is still intact because the shale is weaker and less able to support steep slopes. In most areas, the sandstone hanging wall forming the western side of the trench remains intact.

3.4.2.1 Trench Bottom Stability

Failure of the sandstone footwall may have resulted in voids being left beneath the base of the trench. This potential remnant condition is based on the observations of retired PCC personnel who observed large slabs of sandstone sliding off the footwall into the trench. It is believed that these slabs could mask underlying voids.

A similar method of analysis to that used for extraction ratio calculation has been used to estimate the potential for remaining open voids in the Rogers Seam:

(1) The total volume of rock and coal loosened by booming was calculated by multiplying the total extraction zone area by the width of the booming round (up to approximately 16 ft according to mine records and interviews with retired miners). Total volume calculated as 1,500,000 yd^3.

(2) The volume of bulked rock remaining in situ was estimated by subtracting the volume of raw coal from the total volume and multiplying the result by a bulking factor of 1.35. Total remaining volume calculated as 970,000 yd^3.

(3) The bulked volume of rock which has caved into the mine workings was estimated by multiplying the length of the caved zone (from the 1974 mine map) by the trench cross-sectional area (taken from a section drawn by C. Falk dated 1974) and a bulking factor of 1.35. Caved volume calculated as 400,000 yd^3.

(4) The estimated volume of open voids was calculated by subtracting the remaining in situ and caved rock volume from the total volume, expressing the result as a percentage of the total volume. Calculated as 8%.

Significant uncertainty exists regarding the absolute value of this ratio as the precise volume of originally open trench cannot be determined from the available data and at least one of the personnel interviewed stated that material from outside the trench area was used for backfill during mine operations. As shown in Figure 3-15, backfilling during mining and subsequent deposition of demolition debris has filled all but about 200,000 cubic yards of the original subsidence trench.

A more rigorous engineering analysis of the stability of the trench bottom is not warranted at this stage as conditions below the base of the trench are unknown. Nevertheless, although it is likely that a majority of trench bottom subsidence has already occurred, it is prudent to allow for further subsidence and trench base instability when evaluating and designing any remedial measures.

3.4.2.2 Trench Sidewall Stability

The strata forming the trench sidewall were mapped in trenches that were excavated perpendicular to the trench rim in areas 8 and 9 (Figures F-8 to F-10, Appendix F; and Section 3.3.2.1). The mapped sequence included interbedded sandstone, shale, and siltstone; no evidence of sidewall instability was observed. However, slabbing failure, similar to that observed by retired PCC personnel, may occur if material is removed from the trench bottom or if further subsidence occurs.

3.4.2.3 Potential for Waste Movement After Dumping

According to Evan Morris (Morris, E. 1992) a majority of the drummed waste was deposited in the trench north of the rock bridge (major fault in northern part of mine). The last mining beneath this area was completed at the end of 1967 approximately one year prior to waste deposition. Fourth level mining beneath the trench immediately to the south of the rock bridge began in September of 1970 and was completed in 1974. While there was some potential for movement of the contained waste after deposition north of the rock bridge, it is considered unlikely that significant deformations occurred. There is a modestly higher probability that waste in the trench to the south of the rock bridge has settled since deposition. Settlement of the waste could result in debris moving down into the mine.

3.5 Surface Water and Meteorologic Characteristics

This section describes the surface water and meteorologic characteristics of the Study Area vicinity. Information was collected from a number of sources including review of available technical literature, computer databases and site reconnaissance.

3.5.1 Surface Water

The major surface water features at the Study Area are the Cedar River along the Study Area's northern boundary and Rock Creek within the southern boundary. The Study Area is situated along a drainage divide separating the Cedar River mainstem and the Rock Creek Subbasins. Drainage from the northern half of the site flows to the Cedar River mainstem, while drainage from the southern half of the site flows into the Rock Creek subbasin. Rock Creek ultimately drains into the Cedar River approximately 2 miles downstream of the site. In addition to these major features, the site itself contains a number of small minor unnamed and primarily ephemeral drainages and shallow depressions. These features of the Study Area are discussed below. Figure 3-16 depicts the primary surface water flow pattern and features of the Study Area.

3.5.1.1 Cedar River

The major surface water characteristic in the Study Area vicinity is the Cedar River which is located approximately 500 ft from the northern end of the trench. The Cedar River valley drainage system extends from the south end of Lake Washington to the crest of the Cascade Range (King County Dept. of Public Works 1993). Major features of the system include Lake

Washington, the Rock Creek tributary, and the City of Seattle water intake structure at Landsburg.

The largest lake in the system is Lake Washington which is presently the endpoint for water flowing westward from the Cedar River. The Cedar River supplies approximately 54% of Lake Washington's supply. The river is considered a significant regional water supply providing 70% of the water needs for the City of Seattle and surrounding areas (King County Dept. of Public Works 1993).

The Cedar River is of A (excellent) quality from Lake Washington to the State Highway 169 overpass in Renton, Washington. Nearer to the Landsburg Mine site, the river has been rated AA (extraordinary) which is described as "markedly and uniformly exceeding the requirements for all or substantially all beneficial uses." Water quality in the Cedar River mainstem is considered excellent (King County Dept. of Public Works 1993).

Flow data for the river are available for two gaging stations located in the Study Area vicinity (Hydrosphere Data Products 1993b). The USGS maintains a gaging station approximately 1 mile upriver of the diversion. Data for this station are available for the period 1895 to 1994. Below the diversion structure, a gaging station is operated by the City of Seattle. Data for this period are available only for 1992 to 1994. Table 3-7 summarizes the daily average flows in the river by month for each of these two stations. As seen in the table, above the diversion structure the daily average flow varies from a low of approximately 322 cfs in September to a maximum of about 975 cfs in January. A long, relatively wet season is indicated from November through June where average daily flows vary between approximately 700 and 975 cfs. The dry season is July to September with average daily flows of about 300 to 500 cfs. Below the diversion, data compiled from 1992 to 1994 indicate the daily average flow in the river varies from a high of only 591 cfs in December to a low of 160 cfs in September. The difference between daily average flows at the two gaging points is generally in the 150 to 450 cfs range. This presumably represents the approximate diversion taking place at the City of Seattle diversion structure.

3.5.1.2 Rock Creek

Rock Creek is located in the southern portion of the site and is tributary to the Cedar River. The creek represents the only perennial creek or stream within the Study Area boundaries. The creek becomes ephemeral in the south-central portion of the Study Area approximately where it crosses under the Kent-Kangley Rd. (Figure 3-16). The relatively high flow rate which is generated within several hundred ft of this point indicates the creek is gaining in the portion located within the Study Area (i.e. sustained by groundwater discharge). Presumably the source of flow in the creek is groundwater inflow from the east through the permeable glacial outwash deposits.

The Rock Creek sub-basin drains over 7,000 acres and is considered to be the least disturbed and most pristine of the five tributary subbasins of the Cedar River (King Co. Dept. of Public Works 1993). Based on the pristine, rural nature of the area, the water quality in the creek is thought to be very good although few data are available.

Flow data for Rock Creek near the City of Kent diversion was available for the years 1945 through 1948. The average daily flow for this time was 29 cfs. Daily averages for the creek over this period varied from a minimum of 6.3 cfs in August to 56 cfs in December (Hydrosphere Data Products 1993b).

3.5.1.3 Site Drainage Features

The mine site itself has only ephemeral drainages which discharge during prolonged or intense periods of rainfall. The southern portion of the mine site drains towards Rock Creek and the northern half drains to the Cedar River. The generalized surface water flow patterns at the site and the locations of major features are shown in Figure 3-16.

The lower elevations around the perimeter of the Study Area are covered by relatively permeable outwash sands and gravels at the land surface without defined drainage patterns. Rainfall is expected to readily infiltrate these materials. The elevated portions of the site either have surface outcrops of bedrock or a thin veneer of glacial drift (till) which will inhibit infiltration relative to the permeable outwash deposits. In general then, surface water flow at the site is expected to run-off the hills, collect in ephemeral drainages and flow to the lower elevations where it infiltrates into the outwash deposits or flows into Rock Creek or the Cedar River. Some run-off also flows into the mine trench, depending on the local topography and drainage patterns. Run-off flowing into the mine trench collects in several ephemeral pools where it infiltrates or evaporates.

Field reconnaissance by GAI personnel confirmed six wet areas within the trench or immediate vicinity (Figures 3-16 and 3-17). Two of these consist of the mine portals #2 and #3. Water occurrence at these locations is perennial and is expected to represent natural groundwater discharge, as discussed in Section 3.6. Another, the so-called "sludge pond" located just to the north of well LMW-1, is also perennial. The other four areas consist of localized pools which are ephemeral and have been observed to go dry during the months of June through November. These pools, as discussed in Section 3.6, are not believed to represent groundwater, but rather are more accurately characterized as ephemeral pools of surface run-off which flows into the trench due to local topography and is then temporarily retained.

The water present at portal #2 occurs as a pool which is completely retained and enclosed as a shallow depression. Drainage from portal #2 at the north end of the mine was reported during earlier investigations by Ecology and Environment in February 1991, but was not observed by GAI at any time during the RI. Portal #3 occurs as seepage where water emanates along a sloping seepage face, flows along the ground surface for a short distance, and gradually re-infiltrates back into surficial soils. Surface water run-off from portal #3 was never observed to extend beyond the Kent-Kangley Rd. Flow rates measured at the portal during this RI (shown in Appendix B) varied from about 2 gpm to 100 gpm with the minimum flow occurring in late summer and the maximum flow occurring in winter.

Other localized pools or shallow ponds also occur in the Study Area. These are shown in Figure 3-16. One is located along the southwest side of the hill located to the east of the trench. This pond is located along one of the major ephemeral drainages at the site and is perennial. Discharge from the pond occurs through a culvert which passes beneath the adjacent dirt road.

Discharge through the culvert apparently ceases during the summer months. Two other shallow ponds, which are also associated with the major ephemeral drainages at the site are present along the north side this hill. Miscellaneous occurrences of standing water at the higher elevations are common in the wetter months.

3.5.2 Meteorological Characteristics

3.5.2.1 Regional Characteristics

The climate of the Puget Sound region is typified as a marine climate with cool summers and mild, rainy winters. Summer temperatures generally remain below 80° Fahrenheit. Winter temperatures are usually above freezing. Warm, moisture-laden winds move landward from the Pacific Ocean and are forced upward by the west slope of the Cascade Mountain Range. As the air rises, it is cooled and the resulting condensation of moisture produces precipitation in the form of rain and snow. The wet season will typically last from October to March. Because of mild winter temperatures, the growing season is long and conducive to the development of dense evergreen forest (Brown and Caldwell 1978b).

Within the Cedar River Basin, temperatures are considered moderate and precipitation ranges from snowfalls of 200 inches per year in the Cascade Mountains, to 100 to 200 inches of precipitation in the upper basin, to about 30 to 50 inches in the middle and lower basins where the Landsburg Mine site is located (King County Dept. of Public Works 1993).

3.5.2.2 Site Characteristics

Meteorological data for the site were obtained for the weather observation station located at the City of Seattle intake structure on the Cedar River at Landsburg (Hydrosphere Data Products 1993a). These data consists of monthly precipitation, snowfall, and temperature data for the years 1931 through June of 1993. The data are summarized in Tables 3-8 and 3-9.

The climatological data indicates that for nearly sixty years the average precipitation at the site ranges from slightly less than 1.5 inches in July to nearly 8 inches in December. In general, the months of July through September are driest, and October through January are the wettest. Yearly precipitation averages 56.52 inches with a maximum of 76.39 and a minimum of 32.93 inches.

Snowfall data for the site indicates that on average 10.61 inches of precipitation falls as snow. The highest recorded monthly snow fall occurred in January of 1950 when more than 35 inches of snow fell.

On average, January is the coldest month and August the warmest with average daily low temperatures ranging from 37° F to 49° F and average daily maximum temperatures ranging from 51° F to 85° F. The lowest recorded temperature was 18° F recorded in January 1950. The highest recorded temperature was 85° F in August 1967.

In addition to the monthly data discussed above, additional data consisting of daily climatological observations for the station at Landsburg for December 1993 to January 1995 were obtained directly from the Seattle Water Department. These data cover the period of the RI. Daily precipitation amounts are plotted in Appendix B. The maximum daily precipitation measured over this time period was about 2 in. 24-hour rainfalls in excess of 1 in. occurred on 4 occasions.

3.6 Groundwater Characteristics

This section describes the regional, Study Area and mine-specific (site) hydrogeologic conditions. As with Section 3.3 (Geologic Conditions), the regional description refers generally to the southwestern portion of King County. The description of regional and Study Area hydrogeology is based primarily on Luzier (1969) and studies of the Cedar River groundwater basin presented in Brown and Caldwell (1978a,b, 1980). Site conditions are described primarily on the basis of the field investigative activities conducted as part of this RI.

3.6.1 Regional Hydrogeology

As discussed in Section 3.3, the Study Area is situated along the eastern margin of the Puget Sound Lowland, a broad glacial drift plain that merges eastward with the glaciated foothills of the Cascade Range. The foothills are the protruding parts of a Tertiary bedrock surface (Puget Group sedimentary rocks) that descends westward beneath the Quaternary drift deposits more than 1,000 ft thick. The Tertiary bedrock materials together with the glacial drift comprise the two primary hydrostratigraphic units in the region.

Tertiary rocks are a secondary source of groundwater in southwestern King County (Luzier 1969). The relatively fine-grained nature of the Puget Group sediments precludes the possibility of obtaining well yields more than about 50 gpm. Groundwater movement through these materials is chiefly through joints, bedding planes and faults. Luzier (1969) reported that large yields could be obtained by drilling into flooded mine workings; however, the use of such water could be limited by water quality.

Quaternary deposits are the chief source of groundwater in the region. They form a lens-shaped mass that may exceed 2,000 ft in thickness in the central portion of the Puget Sound Lowland. Along the eastern margin of the Lowland, such as in the Study Area, these deposits thin and pinch out in places in the vicinity of bedrock highs and along the Cascade Range.

The most productive aquifers in southwestern King County are the buried valley fills of Vashon advance outwash, thick ice-contact and recessional outwash deposits also of Vashon age, and outwash bodies of Pre-Vashon drift, such as the Salmon Springs Drift. These deposits can be highly productive and wells commonly yield 300 to more than 2,000 gpm. Recessional outwash and ice-contact deposits give rise to springs with discharges that range from 1,000 to more than 20,000 gpm. These springs are the principal sources of water for the cities of Kent, Auburn, Black Diamond and Enumclaw (Luzier 1969).

Vashon till forms a relatively thin but areally widespread and nearly impermeable blanket over most of the glacial drift in the region. The low permeability of the till restricts recharge to underlying groundwater, and often results in the formation of peat bogs, swamps and lakes.

Where till is overlain by recessional outwash, perched groundwater is likely to occur. In other areas, the till may be important as a confining layer. Despite the low permeability of till, small domestic supplies of water have been obtained from numerous uncased shallow wells dug into the till. The wells are generally less than about 30 ft deep and from 3 to 6 ft in diameter. The chief sources of groundwater for these wells are perched water-bearing zones in the upper less-compact part of the till. These wells generally supply meager supplies of water and often go dry in late summer.

Groundwater is confined or partially confined in most Pleistocene aquifers older than Vashon till, and is unconfined in the Vashon recessional outwash and most alluvial aquifers. The water table and piezometric surfaces fluctuate less than about 10 ft per year in response to seasonal changes in groundwater storage.

The chemical quality of most groundwater in the region is excellent for drinking purposes. Iron-rich groundwaters occur irregularly with apparently little systematic relationship to individual geologic units. Luzier (1969) reported that organic-rich deposits such as peat may contribute to the presence of iron in groundwater. The least mineralized water occurs in the Vashon recessional outwash and ice-contact deposits in the eastern part of the glacial drift plain. These deposits are recharged almost entirely by precipitation whereas most of the other important aquifers, because of their stratigraphic or topographic position, are indirectly recharged by movement of groundwater from overlying, adjacent or underlying geologic units.

3.6.2 Study Area General Conditions

The Study Area is located within the Cedar River groundwater basin. Consistent with the regional view, the primary hydrostratigraphic units of the basin and Study Area include: 1) the Quaternary glaciofluvial outwash and recent alluvium deposits of interstatified clay, silt, sand and gravel; and 2) Tertiary bedrock composed of interbedded sandstones, shales, siltstones and coal seams of the Puget Group.

The most productive aquifers are the glaciofluvial outwash and alluvium deposits. These materials are characterized by permeabilities orders of magnitude greater than the permeability of the bedrock. As such, the majority of the groundwater flow within the basin occurs through the outwash sands and gravels. The Mine site and the central portion of the Study Area are situated atop a Puget Group bedrock high which protrudes up through permeable deposits of glacial outwash. Groundwater flow through these outwash deposits occurs primarily from east to west. In the vicinity of the Study Area, groundwater moving in through these deposits from the east is diverted around the bedrock hills through the valley fill deposits present in the lower elevations around the perimeter of the Study Area. At the southern portion of the Study Area, these flows discharge to Rock Creek and are the principle source of water at the City of Kent Clark Springs water intake. Generalized directions of groundwater flow within the valley-fill deposits are illustrated in Figure 3-18.

Due to the interbedded nature of the Puget Group deposits and the presence of fine-grained siltstones and shales, groundwater flow across bedding is expected to be very small. Groundwater flow within the bedrock aquifer is expected to be controlled by the more permeable strata and structural features.

Due to the presence of the bedrock high discussed above, glaciofluvial deposits are generally less than about 100 ft thick in the Study Area. Approximately 1 to 2 miles to the northwest of the Study Area, over the central portion of the Cedar River basin trough, these materials thicken to in excess of 700 ft (Brown and Caldwell 1980). This area was the subject of a preliminary evaluation by the City of Seattle in the late 1970s to determine if a 30 to 90 mgd well field could be developed to augment water supply during Cedar River low flows. Field investigations conducted as part of the study revealed a thick sequence of permeable glacial valley fill representing the full cycle of Vashon aged glacial advance and recession overlying several units of pre-Vashon drift. At least two areally extensive, confined artesian aquifers of pre-Vashon age were identified and judged to be capable of sustaining high production rates from a well field.

The primary source of groundwater throughout the Cedar River basin is precipitation. Aquifer recharge occurs mainly during the winter and spring wet season. Recharge mechanisms include direct infiltration of precipitation, aquifer underflow from adjacent aquifers, leakage from surface streams that drain elevated bedrock areas, and intercommunication between the valley-filled outwash deposits and the bedrock.

The mechanisms of groundwater discharge include seepage into surface steams, discharge at wells and springs, evapotranspiration and aquifer underflow out of the Study Area. Other than evapotranspiration and well discharge, all groundwater within the Study Area ultimately discharges to the Cedar River as seepage. Stream gauge data confirm that the Cedar River gains throughout its course in the Cedar River Basin (Brown and Caldwell 1978). Discharge from private wells and springs are considered to be relatively small, with the possible exception of the City of Kent's Clark Springs extraction system in the Rock Creek alluvial system.

3.6.3 Mine Site Groundwater Conditions

3.6.3.1 Groundwater Occurrence

Groundwater at the Mine site occurs within the following geologic units:

- sedimentary bedrock of the Puget Group,
- the glacial outwash materials present in lower elevations of the Study Area, and
- the relatively thin glacial drift (till) which mantles the Puget Group bedrock along the hill sides.

The first two of these comprise the primary groundwater flow system at the Study Area. Groundwater in the latter of these represents relatively minor occurrences of perched groundwater and is of secondary importance. The hydrogeology of each of these materials is discussed in detail below. Water level measurements taken throughout the RI at monitoring wells and portal #2 are summarized and plotted in a series of hydrographs in Appendix B. Water levels are shown in cross-section in Figures 3-9, -10, -11, -12. The piezometric surface of the primary groundwater flow system is shown in Figure 3-19.

3.6.3.1.1 Puget Group

Water Levels/Hydrographs

Within the bedrock deposits, groundwater occurs at depths ranging from about 10 ft to in excess of about 200 ft below ground surface, depending on topographic position. The deeper groundwater occurs beneath the higher elevations of the Study Area and Mine site. For instance, depths to groundwater at wells LMW-1, LMW-7 and PW-6, located in the central portion of the Mine site, are about 140, 215 and 235 ft bgs, respectively. Groundwater occurs relatively close to the ground surface, however, in wells located around the base of the Mine site hill. At wells LMW-2, -3, -4, -5 and -6 the depth to water is all generally less than about 20 ft.

Within the Mine trench itself (Figure 3-9), the depth to groundwater varies from about 150 ft in the central portion of the trench to near zero at either end. This water occurs under water table or unconfined conditions as any potential confining layers are now absent due to mining. Bedrock groundwater elsewhere in the Study Area may occur locally under confined to semi-confined conditions due to the presence of till which mantles much of the area.

Hydrographs of water levels in the site monitoring wells are shown in Appendix B. These cover the period January 1994 through April 1995. As seen in Figure B-1, water levels vary seasonally with the highest levels occurring in winter and spring and the lowest levels occurring during late summer. The amount of seasonal fluctuation varies in the wells from a minimum of about 2 ft at LMW-7 to a maximum of about 30 ft at LMW-6. Water levels at the north and south ends of the trench (wells LMW-2 to -5) vary only a few feet while levels at well LMW-1 in the central portion of the trench fluctuated by about 20 ft.

Hydrographs of wells LMW-2/4 (Figure B-3) show that water levels varied in an identical manner at each well over the one year period. This indicates that the shallow and deeper portions of the coal seam, where the two wells are installed, are hydraulically well-interconnected, as expected. A similar response was observed at the LMW-1/1A (Figure B-2) and the LMW-3/5 well pairs (Figure B-4). Due to the small head difference between the shallow and the deep well at each nested well pair, there is apparently very little vertical gradient within the trench. The gradient is weakly upward at the north end and weakly downward at the south end.

As seen in Figure B-1, water level elevations in the Mine wells (wells LMW-1, -1A, -2, -3, -4 and -5) fluctuate similarly, indicating that these wells are installed in a common hydrostratigraphic unit. However, the water level variation at the wells installed in the adjacent coal seams differs, especially at LMW-6. Water levels at LMW-6 fluctuate considerably more than the Mine wells during the summer months. This suggests that wells installed away from the Mine communicate poorly, if at all, with Mine groundwater.

This is supported by the large difference in hydraulic head (approximately 50 to 70 ft) observed between the mine wells and well LMW-7 (Figure B-1). This difference in head suggests that geologic materials between LMW-7 and the mine (including the fault) are tight and do not provide a permeable pathway for the flow of groundwater away from the mine. The water level variation observed at LMW-6 and the large difference in hydraulic head seen between LMW-7 and the mine wells suggest that groundwater flow away from the mine across bedding (lateral flow) is negligible.

Water levels measured at portal #2 are shown in Figures B-7 and B-8. As seen in the figures, the elevation of water at the portal is intermediate between the elevations at LMW-1 and LMW-2/4, and the levels at each of these points fluctuated identically. This confirms that water at portal #2 represents a surface expression of the water table surface and is fed by groundwater.

As discussed previously in Section 3.5.1, several areas of surface water accumulation were identified during the RI within the trench. These are depicted in Figures 3-16 and -17. Elevation measurements of ponded water at areas 1 and 3 taken April 28, 1994, were 745.2 and 730.9 ft amsl, respectively. As shown in Figure 3-19, the maximum water table surface elevation within the trench is about 650 ft amsl, or at least 100 ft below these measured values. In addition, the elevation in area 3 was about 15 ft lower than in area 1, in spite of the fact that area 3 is located in a topographically higher portion of the mine trench. These observations indicate that these bodies do not represent groundwater but rather ephemeral accumulations of surface water which occur as a result of surface water runoff into the trench.

Recharge/Discharge

Figure B-11 shows measured daily precipitation values at Landsburg overlain on the hydrograph plots. As seen in the figure, increases and decreases in precipitation are generally reflected by corresponding variations in water level. Variations in the discharge rate of water at portal #3 (Figure B-9) also display a seasonal pattern. These patterns of seasonal variation, which closely coincide with wet and dry periods of the year, confirm that bedrock groundwater is recharged through direct precipitation of rainfall. The presence of the trench, which naturally serves as a surface water collection point and lacks any overlying layers of low permeability till which would restrict infiltration, probably accelerates recharge to bedrock materials in the immediate vicinity of the Mine.

Discharge of water from the bedrock materials is strongly controlled by the orientation of bedding. In the horizontal direction, groundwater can flow either laterally away from the mine, or parallel (along strike) to the mine. Evidence presented earlier (Sections 3.3.2.2 and 3.6.3.1.1) indicate that faults are tight and do not serve as significant pathways. Because of the near vertical orientation of bedding at the site, lateral flow of groundwater would have to occur perpendicular to and across the individual bedding layers adjacent to the mine. Parallel flow would occur within the mined-out Rogers seam. The rate at which water can move laterally away from the mine is a function of K_z, the equivalent hydraulic conductivity of the layered system. K_z is strongly dominated by the hydraulic conductivities of the least permeable materials present in the system, since groundwater can only move as rapidly as the least permeable zone will allow. Groundwater flow along strike of the mine, or parallel to the bedding, is a function of K_x, the hydraulic conductivity of the individual bed, in this case of the mined-out seam. The conductivity of this disturbed zone is certainly orders of magnitude larger than the conductivity of individual undisturbed layers paralleling the mine, especially the fine-grained siltstones and shales. As a result, the value of K_z is also orders of magnitude smaller than K_x. This creates a strong preference for flow along strike of the mined out seam rather than laterally away from the mine.

Within this context, flow will generally occur as a subdued reflection of surface topography. In the northern half of the trench, flow is primarily to the northeast since the ground surface elevation of the mined-out seam declines in this direction, and in the southern part of the trench, the flow is to the southwest. From the south end of the trench, water discharges at portal #3 as seepage. This water flows briefly overland before re-infiltrating into the valley outwash aquifer. At the north end of the mine, the trench discharges through the Rogers Seam to the northeast into the adjacent glacial drift materials before reaching the Cedar River. In general then, discharge of water from the Mine site bedrock materials is primarily to the Cedar River with some discharge at the southern end to the Rock Creek alluvium and outwash materials.

3.6.3.1.2 Glacial Outwash

Groundwater occurs within about 5 to 15 ft of the ground surface in the outwash materials around the Study Area perimeter, which are most prevalent in the valley at the south of the site. This aquifer is unconfined and is a part of the large regional system of the Cedar River basin to the east. Areally extensive outwash deposits to the east discharge through the valley fill material located to the south of the site. The total thickness of this aquifer is on the order of 100 ft in the vicinity of the site. Significant flow occurs through this material as evidenced by the discharge which occurs to Rock Creek. Rock Creek is a gaining stream in the Study Area vicinity and is fed by groundwater discharges from the outwash aquifer.

3.6.3.1.3 Till

Groundwater is also present at the site within the glacial drift deposits which mantle the bedrock in the higher elevations. This material consists of compact sand and gravel (till) and reaches thicknesses of up to about 100 ft in some areas. Generally, the material is less than about 50 ft in thickness. Groundwater present in the till is tapped by a number of shallow private wells within the Study Area and is probably perched over the bedrock system.

3.6.3.2 Groundwater Flow Directions

Based on the description presented above, the bedrock materials and the surrounding glacial outwash deposits form a near continuous groundwater system at the Study Area. Minor occurrences of groundwater are also present above the bedrock in the till present at the site. This groundwater is probably perched over the primary groundwater system and is of secondary importance.

A generalized depiction of the piezometric surface of this groundwater system is shown in Figure 3-19. This figure depicts the overall patterns of groundwater flow in the bedrock materials at the site and the surrounding glacial outwash. As seen in the figure, groundwater flow throughout most of the Study Area generally reflects the surface topography. Within the trench, flow occurs along strike to the northeast in the major portion of the trench, and to the southwest in the southern portion of the trench. Discharge occurs at each end to the glacial outwash deposits surrounding the site. Flow is then controlled primarily by surface topography. At the north end of the mine, the discharge continues downslope towards the

Cedar River. At the southern end, the discharge enters into the Rock Creek valley materials and flows downstream to the west.

3.6.3.3 Hydraulic Properties

As discussed in Chapter 2, slug tests and pumping tests were conducted on selected RI monitoring wells to obtain estimated hydraulic conductivity values. The results are summarized below. Full details regarding analytical methods and results are presented in Appendix F. A summary of results showing the estimated values of hydraulic conductivity determined from the slug tests is shown in Table 3-10.

3.6.3.3.1 Slug Test Analytical Results

The results of the slug test analyses demonstrate that the Rogers Seam is highly conductive. Calculated hydraulic conductivity values for wells LMW-2, LMW-4, and LMW-5 are quite high and range from about 0.009 to 0.036 ft/s (0.3 to 1.1 cm/s). Those for LMW-3 and LMW-1 are several orders of magnitude lower (10^{-5} to 10^{-6} ft/s).

These results generally confirm the view that the Rogers coal seam is highly conductive and capable of transmitting a large quantity of water. This conclusion is not surprising considering the wells were located within or near previously mined or altered portions of the coal seam where large void spaces are known or suspected to exist. The results of the LMW-3 slug testing, which suggest a hydraulic conductivity which is two to three orders of magnitude lower than those calculated for LMW-2, LMW-4 and LMW-5 (see 3-10), may be representative of hydraulic conditions in unaltered coal. Test results for well LMW-1, which was completed within the sandstone adjacent to the Rogers Seam, suggests that the sandstone has a hydraulic conductivity at least four orders of magnitude lower than the portions of the mined-out Rogers Seam.

3.6.3.3.2 Pumping Test Results

Pumping test hydrographs and discussion of results are presented in Appendix F. As discussed in Appendix G, the data generated by the two pumping tests was generally not useable for data analysis purposes as a result of very low pumping rates and correspondingly small drawdowns in the highly conductive material. Qualitatively, however, the data do generally support and confirm the slug test results which indicated extremely high conductivity of the material within the Rogers coal seam.

3.6.3.3.3 Baker Tank Discharge

Water collected in Baker tanks was drained at two site locations, one of which was directly within the trench. During the discharge of this water, dataloggers were installed in wells LMW-1, -3 and -4 to monitor any resulting water level changes. The plot of the observed water levels in these wells is shown in Figure B-12. Wells LMW-6 and LMW-7 were manually monitored (infrequently) during the test. The pond at portal #2 was monitored visually. The results of the monitoring at LMW-6 and -7 are shown in Table B-2. Private wells were not monitored because of the difficulty in obtaining access, and because LMW-6 and LMW-7 were already being monitored.

Water was introduced at the north end of the trench in the immediate vicinity of portal #2 (Figure 2-14), and at the south end of the site at a location some 200 ft to the northeast from portal #3 (Figure 2-15). Disposal at the north end occurred directly to the trench. Disposal at the south end was outside the trench and away from the Roger's seam. At the north end, water was drained from 1:45 to 8:10 pm on August 16, 1994. At the south end, water was drained from 11:42 AM to 12:32 PM on the same date. Approximately 3,200 gallons were drained at the south end, and about 24,700 gallons at the north end. While it is not possible to analyze these data quantitatively to assess hydraulic properties of the coal seam, the data can be qualitatively evaluated.

Changes in water levels were noted at wells LMW-1 and -4. The water level increased at LMW-1 by about 1 ft and at LMW-4 by about 0.3 ft. The water level at LMW-3 was essentially unchanged. The lack of response at LMW-3 is not surprising given that the discharge point was downslope from the well and the water was not introduced directly into the coal seam.

The water level responses at wells LMW-1 and -4 occurred very rapidly following the introduction of the water. Water levels began to increase in both wells within about 1 to 2 hours. LMW-1 is approximately 800 ft away (upslope) from the discharge point, and LMW-4 is about 300 ft away (downslope). Water was pumped at the north end for about 6.5 hours. The water levels began to decline in each well about 30 hours following the cessation of pumping. Neither well had returned to its original level when the water level measurements were discontinued, which was about 60 hours after the cessation of pumping for LMW-1 and about 130 hrs after the cessation of pumping for LMW-4.

Based on visual observations, the pond water at portal #2 rose several inches during discharge. As shown in Table B-2, no effects were observed at wells LMW-6 and LMW-7.

These observed results generally support the contention that the Rogers coal seam is highly conductive and capable of rapidly transmitting large quantities of water. Water introduced into the trench, either as precipitation or waste, moves quickly downward through the collapsed mine workings to the water table where it then moves rapidly to either the northerly or southerly mine discharge points. The travel time of any liquid materials potentially released to the trench is quite small and may be on the order of hours from the time of release. Evidence for lateral migration away from the mine was not provided.

Given the rapid water level response which occurred at well LMW-1 following Baker tank discharge, these results also indicate that the two portions of the trench separated by the fault in the vicinity of well LMW-1 are in good hydraulic communication with each other. This would indicate that the rock tunnel installed through the fault, and/or other mine workings in the vicinity of this part of the mine, allow effective hydraulic communication through the fault area, and the two portions of the trench are not isolated from each other by the fault offset. The mine may therefore be thought of as forming one relatively continuous, highly conductive zone.

3.6.3.3.4 Mass Balance Calculation

Another method of estimating the hydraulic conductivity of the Rogers Seam is to examine the mass balance of flow in the trench. As discussed earlier in section 3.6.3.1.1, recharge of groundwater in the trench is expected to occur primarily as a result of direct rainfall infiltration and runoff from surrounding areas. As shown in table 3-8, an average of about 55 inches of rainfall falls annually at the site. Given that no runoff of this water occurs in the trench and that evapotranspiration is probably very low, it is reasonable to expect very nearly all of this rainfall actually infiltrates to the water table. Since the trench is about 4,000 ft in length and approximately 50 ft in width, the average flow rate through the trench (and discharge from the two ends) is therefore estimated to be about 10 to 20 gpm.

The hydraulic conductivity for the mined out seam can be estimated by dividing this flow rate by the hydraulic gradient and cross-sectional area of flow. Assuming that the flow is split evenly between the two ends of the trench, and assuming a gradient of about 0.005 and cross-sectional area of 16 ft by 100 ft, the hydraulic conductivity is estimated at about 3 to 5 cm/s. This is in reasonable agreement with the results of the slug test analyses.

3.6.3.3.5 Summary of Hydraulic Analyses

The results of these hydraulic analyses indicate the following:

- The Rogers Seam is highly conductive and capable of rapidly transmitting high quantities of water.

- The fault in the vicinity of LMW-1 does not appear to act as a significant barrier to flow between the north and south portions of the mine. The two portions of the trench separated by the fault are therefore in good hydraulic communication with each other, and the mine may be thought of as forming one relatively continuous, highly conductive zone. This is because the rock tunnel installed through the fault, and/or other mine workings, allow effective hydraulic communication through the fault area.

- The hydraulic conductivity of the mined out Rogers Seam is probably on the order of about 1 to 5 cm/s, based on well tests and mass balance considerations. The conductivity of the surrounding bedrock strata is several orders of magnitude lower.

3.6.3.4 Geochemistry

The inorganic chemistry data have been compiled and presented for visual inspection in Figures 3-20 through 3-23 for the four rounds of groundwater sampling, respectively. These figures, termed Piper diagrams, are useful for visually describing differences in major-ion chemistry in groundwater flow systems and identifying major groupings or trends. Review of these figures results in the following observations.

There is essentially no differentiation between the samples on the basis of the anionic composition. Bicarbonate (HCO_3^-) is the dominant anion in all of the samples analyzed. Bicarbonate content in groundwater is usually derived from interactions between soil zone CO_2 and calcite ($CaCO_3$) and dolomite ($MgCO_3$). These minerals, which occur in significant amounts in nearly all sedimentary basins, are readily soluble in contact with CO_2-charged water (Freeze and Cherry 1979, p. 242-243).

With respect to the cationic composition of the samples, however, two general groupings of wells can be discerned. The first, a calcium-dominant type groundwater, consists of wells LMW-1 through LMW-6, samples of mine groundwater discharge collected at the portals, and the private wells installed in the glacial outwash deposits surrounding the site, or in till overlying the Puget Group (as in PW-7). The second grouping, a sodium-dominant type groundwater, consists of the relatively deep wells completed in Puget Group materials located away from the mine. These include wells LMW-7, PW-5, -6, -8, -14 and -15.

The occurrence of Na^+ and HCO_3^- as the dominant ions can be explained by the combined effects of cation exchange and calcite or dolomite dissolution. High Na-HCO_3 waters can be produced in sequences of strata that have significant amounts of calcite or dolomite and clay minerals with exchangeable Na^+ (Freeze and Cherry 1979, p. 287). As stated above, calcite and dolomite are present in nearly all sedimentary basins. The shales and coal-bearing layers of the Puget Group may afford suitable opportunities for the exchange of calcium and magnesium with sodium.

The interpretation offered, therefore on the basis of these data, is that the Ca-bicarbonate groundwater type represents younger groundwater derived from relatively recent rainfall runoff and infiltration that has followed a relatively short flowpath from the recharge zone. The Ca^{2+}, Mg^{2+} and HCO_3^- in this water are derived from CO_2-rich rainfall and the dissolution of calcite and dolomite in the soil zone. The Na-bicarbonate groundwater, on the other hand, represents older groundwater that, while originating as rainfall runoff, has followed a longer flowpath. During the course of this flowpath, the water has encountered a series of fine-grained sedimentary layers, including siltstones, shales and/or coal beds, where cation exchange has taken place thereby replacing the Ca^{2+} and Mg^{2+} with Na^+.

Groundwater within the undisturbed (unmined) portions of the Puget Group is therefore isolated to an extent from the mine site groundwater. If the Puget Group wells away from the mine were in direct hydraulic connection with mine groundwater, through a fault conduit for example, the cation-anion composition of these wells would be more similar to that observed at the mine wells. This interpretation is significant because it supports the view, stated above in Section 3.6.3.1.1, that the movement of groundwater laterally away from the mine is negligible.

3.6.4 Conceptual Model of Site Groundwater Flow

This sub-section summarizes the characterization of Study Area and Mine site hydrogeologic conditions into a conceptual model of site groundwater flow and potential transport of chemicals. This conceptual model is a general description which, while not addressing every aspect of groundwater hydrology at the site, is sufficient to gain an overall understanding of groundwater flow patterns and conditions and potential chemical receptor points. This conceptual model is based on the information presented in Sections 3.6.1, 3.6.2 and 3.6.3. The reader is referred to these sections for additional details regarding groundwater conditions at the Mine site.

3.6.4.1 Groundwater Flow

The primary hydrogeologic system at the site consists of a continuous to semi-continuous groundwater system comprised of the Puget Group bedrock materials and the surrounding glacial outwash aquifer. Minor occurrences of groundwater in till overlying the bedrock are likely perched and of secondary importance. The bedrock materials, which make up the hills within the Study Area, protrude up through and discharge to the glacial outwash which fills the surrounding valleys and lower elevations around the perimeter of the Study Area.

The trench of the Rogers coal seam is highly permeable with hydraulic conductivities on the order of 1 to 5 cm/s. The two portions of the trench separated by the fault near LMW-1 are in good hydraulic communication with each other, and the mine may be thought of as forming one relatively continuous, highly conductive zone or conduit. The effective hydraulic conductivity of the fine-grained sediments located to either side of the seam is at least several orders of magnitude less than the mined out seam. Faults through the coal seam are probably tight and do not act as significant conduits, based on the regional state of stress, mine reports, water level measurements, and geochemical analyses. Vertical gradients, and therefore vertical flow, also appear to be small within the coal seam. Therefore, groundwater flow in the trench primarily occurs horizontally and along strike through the highly permeable mined out Rogers Seam. Flow laterally away from the Mine (across bedding or via faults) is considered negligible. The trench can therefore be thought of as a highly conductive "slot". Groundwater within this "slot" moves longitudinally, with very little movement laterally away from the trench.

Since lateral flow away from the mine is not considered to be an operable pathway of groundwater flow, wells which are installed in Puget Group materials laterally away from the mine are considered hydraulically isolated from the mine workings. These include wells LMW-6 and LMW-7, installed in the adjacent coal seams, and the private wells completed in Puget Group bedrock materials to the east and west of the mine (i.e., PW-5 through -8, and PW-14 and -15). This is important because it indicates that there is no observable pathway for chemicals to migrate to these wells from the mine.

Mine reports, geochemical data, and the rapid response of groundwater levels to seasonal rainfall patterns suggests that recharge of the coal seam is primarily by direct rainfall infiltration. The trench effectively collects and concentrates rainfall and runoff from the surrounding area. This runoff readily infiltrates through the porous structure of the mined out seam.

Due to the preference for longitudinal flow within the trench and site topography, and as evidenced by the discharge observed at portals #2 and #3, discharge from the mine occurs at either end. A groundwater divide is therefore present within the trench. To the north of this divide, flow is to the north, and to the south of the divide, flow is to the south. There is some uncertainty with respect to the location of this divide, however, based on the high conductivity of the trench, topography and presence of ponded water in the trench, the divide is believed to occur within the southern third of the mine. The majority of flow from the mine and in particular that portion of the mine trench utilized for waste disposal is therefore to the north.

Mass balance considerations, flow measurements made at portal #3, and the reports of mine dewatering have indicated that the total flow rate of water entering as infiltration and exiting near the portals is on the order of about 10 to 20 gpm.

3.6.4.2 Primary Potential Pathways and Receptors

Geophysical data and historical information presented in this RI have indicated that potential waste buried beneath the bottom of the trench is generally confined to the northern half of the site. Given that groundwater flow beneath this portion of the site is to the north, the primary pathway of contaminants potentially exiting the mine is to the north. Future groundwater monitoring activities should therefore focus on detecting potential releases at the northern end. The chance that such a discharge could occur at the southern end is considered unlikely given the direction of groundwater flow and the apparent absence of waste in this portion of the Mine.

Once exiting the site, any potential chemical constituents leaving the northern portion of the mine will flow primarily to the north and northeast towards the Cedar River, consistent with the local ground surface topography. Discharge to the river would occur at a point approximately one mile downstream of the City of Seattle's water intake at Landsburg. This flow will occur within the Rogers coal seam, which presumably extends downslope towards the river, and within the glacial outwash materials which overlie the coal. This is consistent with the observation by field personnel of springs and seeps along the slope leading down to the river. Figure 3-19 depicts the piezometric surface contours of the site groundwater system. Figure 3-24 depicts the primary pathway of potential mine chemicals exiting the site. As seen in the figure, there are no drinking water wells located along the primary pathway of groundwater flow.

While the primary groundwater flow direction is towards the river, it is also possible that some flow could occur to the northwest within the glacial outwash to the north of the mine. If groundwater flows in this direction, potential receptor points would include wells PW-4 and PW-3 and the other private wells located along the Summit-Landsburg Rd (Figure 3-19). Well PW-4 is the closest well and is approximately 1,500 ft away from the trench. It is not considered likely, however, that groundwater flow would occur to these wells given the strong topographic gradient towards the river.

As indicated previously in section 3.6.4.1, wells installed in Puget Group materials and located laterally away from the mine are considered to be hydraulically isolated from the mine workings. There is no observable pathway for chemicals to migrate from the mine to these wells. These include wells LMW-6 and -7, and private wells PW-5 through -8, and PW-14 and -15.

At the southern end of the mine, potential receptors include the cluster of wells along the Kent-Kangley Rd. just southwest of portal #3, and the Clark Springs facility. The series of wells near portal #3 are within about 300 ft of the portal. The Clark Springs facility is approximately 2,500 ft from the portal. It is not considered likely that these wells would ever be impacted, however, as discharge of chemicals from the mine's southern end is considered a very remote possibility.

3.7 Social And Ecological Characteristics

Social and ecological data include a description of current land and water use, and ecological issues including identification of endangered species and discussion of sensitive habitats and areas.

3.7.1 Land Use

The Study Area zoning was determined by reviewing zoning maps at the King County Department of Development and Land Services. The zoning codes from the map were updated to reflect the new Title 21A Zoning Code adopted in June 1993. Full implementation of the new Zoning Code is not complete, but is anticipated by June 1995. The site zoning is shown on Figure 3-25. In general, zoning in the Study Area vicinity is intended to protect the forest resources of the area, to encourage moderate rural development and to protect water quality in the Cedar River and Rock Creek watersheds.

The bulk of the Study Area, including much of the central portion of the site and the former mine workings, has been assigned an RA, Rural Area Zone classification. This zoning, formerly classified as G-5 under KCC Title 21, indicates that land use will maintain an area-wide rural character, will prevent urban developments in areas without adequate urban services, preserve environmentally sensitive areas, and minimize land use conflicts with nearby agricultural, forest, or mineral extraction production districts. In addition, permitted uses will limit residential density to be compatible with rural character and which can be supported by rural service levels.

The western portion of the Study Area from the coal mine areas to Summit-Landsburg Road, has been designated F for forest use. This zoning is designed to preserve the forest land base, to protect the long-term productivity of forest land and restrict uses to those which are compatible with forestry. Compatible uses include outdoor recreation, conservation, and protection of municipal watersheds and wildlife habitats.

In addition, to these zoning classifications, the City of Kent and City of Seattle maintain municipal watershed lands along the western and eastern boundaries of the Study Area, respectively, for the protection of drinking water supplies associated with Rock Creek and the Cedar River.

In addition, under the Shoreline Management Plan of King County, the Cedar River shoreline throughout the Study Area vicinity has been designated a 'Conservancy' environment. The Conservancy designation objective is to conserve, protect, and manage existing areas of irreplaceable natural or aesthetic features in their native state while providing for limited shoreline use at public sites (King County Dept. of Public Works 1993). The Conservancy designation for the Cedar River extends from River Mile 3.4 to the river's headwaters.

3.7.2 Water Use

3.7.2.1 Surface Water

The City of Seattle has used the Cedar River as a source of drinking water since 1901. A large water diversion structure exists upstream of the Mine site area at Landsburg. This structure is a 96-inch diameter pipeline that diverts approximately 150 million gallons per day (mgd) from the Cedar River. The structure splits into two 78-inch diameter pipelines which deliver water to the Lake Youngs Reservoir (Brown and Caldwell 1978b) located some 5 miles to the northwest of the site (Figure 1-1).

Rock Creek has been diverted by the City of Kent since the early 1900s for use as a municipal water source. The diversion by the City of Kent represents approximately 26% of the mean annual flow of the creek and the majority of the creeks flow during the low-flow months of September and October (King County Dept. of Public Works 1993). The existing diversion structure, referred to as the Clark Springs Facility, was built in the 1940s and consists of a lateral gravity drainage collection system installed approximately 13 to 15 ft below ground surface in the creek alluvium. This facility was sampled as part of this RI and was referred to as the Clark Springs Well (PW-13).

3.7.2.2 Groundwater

Groundwater at the Study Area is used for domestic supply, small community water supply systems and for a municipal water supply (City of Kent). Table 2-1 provides the results of a survey of private wells conducted in the Study Area. The table summarizes relevant information including well depth and construction, date of installation, number of houses served, and depth to water. Available well logs for study area private wells are included in Appendix B.

The survey identified a total of 56 wells within the Study Area. Excluding the Clark Springs facility which serves the City of Kent, these wells serve approximately 91 homes at the Study Area and 236 people. The wells were installed since about 1930 with the majority of the wells being installed since about 1970.

The wells range in depth from less than twenty feet to a maximum depth of about 400 feet. Water levels in the wells ranged from as little as 4 feet to as much as 235 feet below ground surface. Many of the shallow wells were hand dug and range between 20 and 30 feet in depth. During the well survey, GAI was unable to determine a depth to water primarily due to access problems for many of the shallow wells. The shallow wells are presumably installed in the glacial drift, while the deeper wells extend into the bedrock materials of the Puget Group.

Forty-six of the wells are domestic service wells providing water to a single residence. Two wells provide water to two residences, and one services four homes. Four of the wells service community water supply systems. These wells, New Arcadia (PW-1), Landsburg Estates (PW-4), Well 429641 (PW-3), and Bridal Trails South (PW-9) provide water to 37 homes around the Study Area. All of the community supply wells were sampled during the remedial investigation.

The City of Kent Clark Springs well (PW-13) is a branched lateral gravity drainage system installed in the Rock Creek alluvium, as discussed above in Section 3.7.2.1.

3.7.3 Ecology

Ecological data collected as part of this RI/FS included identification of endangered and threatened species, priority habitats and species, and sensitive areas. These are described below in Sections 3.7.3.1, 3.7.3.2, and 3.7.3.3, respectively, and are depicted in Figure 3-26.

Information concerning endangered or threatened species was gathered via correspondence with the United States Fish and Wildlife Service (USFWS) and the Washington State Department of Wildlife (WDW).

The WDW provided information about priority habitats and species, nongame heritage database listings and spotted owl sites. The Priority Habitats and Species (PHS) Maps from depict known use areas by species requiring protective measures. Additional data from the WDW Nongame Heritage Database document point observations of nongame species of concern in the area by reputable sources. This database can include endangered, threatened, sensitive, candidate, and monitor species.

Sensitive areas discussed in Section 3.7.3.2 are defined by the King County Sensitive Areas Ordinance as lands that are subject to natural hazards and that contain unique, fragile, or valuable natural resources. Sensitive area information was obtained by reviewing the Sensitive Areas maps created by the King County Department of Building, Land Use and Development.

3.7.3.1 Endangered Species

Endangered and threatened species are categorized as listed, proposed, and candidate. Listed endangered species are defined as those species known to be experiencing or that have experienced failing or declining populations due to factors such as limited numbers, disease, predation, exploitation, or loss of suitable habitat. Proposed endangered species are under consideration for protection. Candidate species are species that may be proposed and listed in the future.

The USFWS identified the bald eagle as the only listed endangered species sighted near the Study Area. The search area for this determination represented an approximately one mile search radius extending from the Study Area and included Sections 23 to 26 of Township 22 North, Range 06 East, and Sections 19 and 20 of Township 22 North, Range 07 East. Bald eagles may winter within this area from approximately October through March.

Several candidate species were also identified by the USFWS as potentially occurring in the Study Area. These include the bull trout, mountain quail, northern goshawk, northern red-legged frog, northwestern pond turtle, pacific fisher, and the spotted frog. The USFWS did not identify any proposed species in the Study Area vicinity.

3.7.3.2 Priority Habitats and Species

3.7.3.2.1 Habitats

Priority habitats consist of any habitat type with unique or significant value to many species. Of primary relevance to this RI are wetlands and critical fish habitat.

Wetlands

"Officially" identified (i.e. mapped) wetlands occur in two areas within the Study Area. These were mapped on the WDW PHS maps and the King County Sensitive Areas maps. These areas are shown in Figure 3-26. In this discussion of wetlands, there is some overlap with Section 3.7.3.3 below since wetlands are also a type of Sensitive Area, as defined by the Sensitive Areas ordinance.

The first of these consists of an area identified by the WDW in the northern trench area. This area is indicated as a priority wetland habitat that is a part of the Cedar River wetlands. While field reconnaissance by GAI personnel did identify a number of wet areas within the trench, the area identified by the WDW was never observed to contain water during this RI.

The second area occurs just inside the southern site boundary. The area is identified as a WDW priority habitat part of the Cedar River wetlands. The PHS map indicates this is a palustrine (swampy) environment. Field reconnaissance of this area indicates it is associated with an ephemeral stream. Currently, a number of residences are located within the mapped wetland. This area is also shown on the King County sensitive areas maps, as discussed below.

Other potential wetland areas, not shown on any governmental maps, were identified by GAI field reconnaissance. These include minor wet areas within the trench as well as other areas of ponded water located in the Study Area. Figure 3-26 depicts the potential wetland areas identified by GAI. Final determination, if necessary, of the status of these areas as wetlands would require a site visit by a qualified biologist or ecologist.

Critical Fish Habitats

The WDW has mapped the Cedar River along the northern Study Area boundary as a critical spawning habitat for resident species. This portion of the river has also been identified as an anadromous fish run and as having resident species present.

Rock Creek is not identified as a critical fish habitat by the WDW. However, it is considered a high-quality salmonid habitat and a 2.5 mile stretch of Rock Creek has been designated a Regionally Significant Resource Area by the Cedar River Watershed Management Committee because of the high-quality aquatic habitat it maintains (King County Dept. of Public Works 1993).

3.7.3.2.2 Species

A priority species is defined as a wildlife species requiring protective measures for their perpetuation. The WDW has established three criteria for describing priority species, listed, vulnerable and recreationally important species. A WDW listed species are those officially designated as listed, proposed, and candidate endangered species by the USFWS. A vulnerable species includes those susceptible to population decline because they are uncommon. Recreationally important species are those species with high recreational importance or public profile and are vulnerable to habitat loss or predation.

The WDW indicates that bald eagles are a priority species and have used areas near Black Diamond as a breeding area. In addition, a bald eagle nest was identified by WDW along the Green River Gorge approximately six miles to the south of the mine Study Area. The Upper Green River Gorge was identified as a priority breeding habitat for harlequin ducks.

The WDW Non-Game Heritage Data System documents point observations of nongame species of concern in the area by reputable sources. Osprey were found nesting in two places along the Green River Gorge to the south of the Study Area. A great blue heron colony was found near Black Diamond, approximately five miles south of the Study Area. A western pond turtle was observed near Black Diamond, but was later removed to the Woodland Park Zoo.

There is no spotted owl activity within the Study Area. A spotted owl was noted more than seven miles to the north of the study area at Rattlesnake Mountain in 1993.

3.7.3.3 Sensitive Areas

Sensitive areas as defined by the King County Sensitive Areas Ordinance (Ordinance 9614) consist of land areas described as environmentally sensitive or that are subject to natural hazards, and lands that support unique, fragile, or valuable natural features. These areas include wetlands, areas prone to stream and flood hazards, erosion hazards, seismic hazards, and coal mine hazards. The purpose of the Sensitive Areas Ordinance was to implement the goals and policies of the Washington State Environmental Policy Act and the King County Comprehensive Plan which call for protection of the natural environment and the public health and safety by establishing development standards to protect defined sensitive areas.

Development of land within identified sensitive areas requires special development standards as well as special studies to assesses impacts and to propose adequate mitigation, maintenance, monitoring and contingency plans for those areas.

Sensitive Areas Maps based on the ordinance from King County were reviewed to determine what sensitive areas exist within the Study Area.

A wetland area is defined as being inundated or saturated by ground or surface water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. As discussed above in Section 3.7.3.2.1, there is one small wetland area within the southern site boundary identified in the King County Sensitive Areas map. This wetland is shown on Figure 3-26 and is discussed in Section 3.5. as a potential tributary of Rock Creek. This area is also depicted on the Washington WDW priority habitat and species map as a palustrine (swampy) environment that is part of the Cedar River wetlands. Currently, a number of residences are situated within this area. This area is located over 1,000 ft from the trench.

Streams are considered sensitive areas because of their esthetic values, their ability to provide recreation, support wildlife, and moderate flooding and erosion. The Cedar River is identified as a Class I stream for its length from Landsburg to Renton. This indicates the river is inventoried as a Shoreline of the State under the King County Management Plan. The Cedar River is currently under review for final designation as a Regionally Significant Resource Area (RSRA) by the Cedar River Management Committee (King County Public Works 1993).

Rock Creek to the south of the site is a Class II stream that flows year-round during years of normal rainfall and is used by salmonids. The creek is ephemeral to the east of were it crosses beneath the Kent-Kangley Rd. (Figure 3-16).

Erosion hazards areas are described as areas where soils are susceptible to erosion as a result of development. Factors affecting erosion include the physical and chemical characteristics of the soil, the presence or absence of vegetative cover, slope length and gradient, the intensity of rainfall and velocity of runoff. Two large areas of the site are described as susceptible to erosion. The first is the steep northern slope along the Cedar River. The second is the steep hillside in the eastern portion of the study area between the trench and Study Area boundary. These areas are shown in Figure 3-26.

Landslide hazard maps delineate areas where the topographic and geologic conditions indicate a potential for hillslope failure. There are no landslide hazard areas identified for the site. Seismic hazards are defined as areas subject to severe risk of earthquake damage as a result of seismically induced settlement or soil liquefaction. There are no such potential areas identified at the site.

Coal mine hazard areas are mapped because of their potential for gradual or sudden collapse of underground mine workings leading to surface ground failure. Surficial ground collapse can cause damage to structures, as well as personal injury. Additional risk may be posed by the presence of unstable mine spoils piles that are subject to failure. As expected, the portions of the

Landsburg mine site where coal removal occurred are mapped as coal mine hazard areas. These are shown in Figure 3-26.